BACHELOR THESIS – ME 141502

PIPE STRESS & HEAT TRANSFER ANALYSIS OF THERMAL OIL PLANT ON FUEL OIL TANKS OF 17500 LTDW PRODUCT OIL TANKER

JUDA IMANUEL OSVALDO PANGGABEAN
NRP. 4213 101 038

Supervisors :
Taufik Fajar Nugroho, S.T., M.Sc.
Dr. Ing. Wolfgang Busse

DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
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Institut Teknologi Sepuluh Nopember
Surabaya 2017

APPROVAL FORM

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BACHELOR THESIS

Submitted to Comply One of the Requirements to Obtain a Bachelor of Engineering Degree
In
Double Degree Marine Engineering (DDME) Program
Department of Marine Engineering – Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
Department of Maritime Studies
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SURABAYA
JULY, 2017

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The Representative of Hochschule Wismar in Indonesia

Dr. Ing. Wolfgang Busse

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DECLARATION OF HONOUR

I hereby who signed below declare that:

This thesis has been written and developed independently without any plagiarism act. All contents and ideas drawn directly from internal and external sources are indicated such as cited sources, literature, and other professional sources.

Name	: Juda Imanuel Osvaldo Panggabean
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Thesis Title	: Pipe Stress & Heat Transfer Analysis of Thermal Oil Plant on Fuel Oil Tanks of 17500 LTDW Product Oil Tanker
Department	: Double Degree Program of Marine Engineering

If there is plagiarism act in the future, I will be fully responsible and receive the penalty given according to the regulation applied.

Surabaya, July 2017

Juda Imanuel Osvaldo Panggabean
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ABSTRACT

The thermal oil system is one of the important systems onboard. This system is used to heat fuel which will be used in the operation of the main engine, auxiliary engine, and boiler. In its process, it needs suitable equipment (able to withstand the working pressure and temperature) to support the operation of this system.

The thermal oil system is already installed on MT. Parigi, but has not been tested yet. This system will be operated at working pressure and working temperature of 5 kgf/cm^2 and 180°C, respectively. Furthermore, the heat which is produced by thermal oil system must be able to fulfill the required temperature of each fuel tank. Therefore, it is needed some analyses to ensure that the thermal oil system that has been installed on 17500 LTDW Product Oil Tanker is safe to operate and appropriate with the design requirement.

This bachelor thesis analyzes the reliability of pipes that used in thermal oil piping system inside the fuel tanks (heating coil), by doing a pipe stress analysis. This pipe stress analysis is done by using Caesar II Software, with ASME B31.3., as code standard. Moreover, this thesis analyzes heat transfer process along distribution line of thermal oil piping system. This is intended to define is the thermal oil system able to transfer heat according to the designed value.

The result of simulation for pipe stress analysis shows a satisfied result, where the stress that happened in storage tank portside, storage tank starboard, settling tank, service tank portside, and service tank starboard are 12530,5 kPa, 14336 kPa, 3953,1 kPa, 3079,7 kPa, and 3079,8 kPa, respectively. These stress results mean that all stress happened in each heating coil pipe of the tanks are lower than the allowable stress of the pipe, namely 135190,7 kPa. The result of heat transfer analysis also shows a satisfied result, in which the heat transfer process

of thermal oil along distribution line into the fuel oil tanks is appropriate with the design value, namely 180^{o}C for input temperature into the fuel tanks and 140^{o}C for output temperature of thermal oil from the fuel tanks.

Keywords – Thermal Oil System, 17500 LTDW Product Oil Tanker, Pipe Stress Analysis, Heating Coil, Caesar II, Heat Transfer Analysis, Distribution Line, Fuel Oil Tanks

ANALISA TEGANGAN PIPA & PERPINDAHAN PANAS SISTEM THERMAL OIL PADA TANGKI-TANGKI BAHAN BAKAR KAPAL 17500 LTDW PRODUCT OIL TANKER

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ABSTRAK

Sistem *thermal oil* merupakan salah satu sistem atau instalasi yang penting di kapal. Sistem ini digunakan untuk memanaskan bahan bakar, yang mana bahan bakar tersebut nantinya akan digunakan untuk menunjang operasional dari *main engine*, *auxiliary engine*, dan boiler. Dalam pengoperasiannya, sistem ini memerlukan peralatan-peralatan yang sesuai (mampu bertahan pada tekanan dan temperatur kerja) untuk menunjang operasional.

Sistem *thermal oil* tersebut telah terpasang di kapal MT. Parigi, tetapi belum di tes. Sistem ini akan dioperasikan pada tekanan kerja 5 bar dan temperatur kerja 180^{o}C. Selanjutnya, panas yang dihasilkan oleh sistem ini harus dapat memenuhi temperatur yang dibutuhkan oleh masing-masing tangki bahan bakar. Oleh karena itu, diperlukan beberapa analisa untuk memastikan bahwa sistem *thermal oil* yang telah dipasang pada 17500 LTDW *Product Oil Tanker* aman untuk dioperasikan dan sesuai dengan persyaratan desain yang ada.

Skripsi ini menganalisa keandalan pipa yang digunakan pada sistem perpipaan *thermal oil* yang berada di dalam tangki bahan bakar (*heating coil*), yaitu dengan cara melakukan analisa tegangan pipa. Analisis ini dilakukan dengan menggunakan Software Caesar II dan ASME B31.3. sebagai standar kode pipa. Selain itu, skripsi ini menganalisa proses perpindahan panas yang terjadi di sepanjang jalur distribusi *thermal oil*. Hal ini bertujuan untuk mengetahui apakah sistem *thermal oil* yang telah terpasang mampu menghantarkan panas sesuai dengan nilai yang diinginkan.

Hasil simulasi analisa tegangan pipa yang dilakukan menunjukkan hasil yang memuaskan, dimana tegangan yang terjadi pada pipa koil pemanas di *storage tank portside*, *storage tank starboard*, *settling tank*, *service tank portside*, dan *service tank starboard* adalah sebesar 12530,5 kPa, 14336 kPa, 3953,1 kPa, 3079,7 kPa, dan 3079,8 kPa. Hasil ini menunjukkan bahwa nilai semua tegangan yang terjadi pada pipa koil pemanas tangki-tangki bahan bakar lebih rendah dibandingkan dengan nilai tegangan pipa yang diijinkan (*allowable* stress), yaitu 135190,7 kPa. Hasil perhitungan analisa perpindahan panas juga menunjukkan hasil yang memuaskan, dimana nilai perpindahan panas yang terjadi selama jalur distribusi *thermal oil* ke tangki-tangki bahan bakar sesuai dengan desain yang ada, yaitu 180^{o}C untuk temperatur *thermal oil* masuk ke dalam tangki-tangki bahan bakar dan 140^{o}C untuk keluaran temperatur *thermal oil* dari tangki-tangki bahan bakar.

Kata Kunci – Sistem Thermal Oil, 17500 LTDW Product Oil Tanker, Analisa Tegangan Pipa, Heating Coil, Caesar II, Analisa Perpindahan Panas, Jalur Distribusi, Tangki Bahan Bakar

PREFACE

The writer would like to offer his gratitude to the Almighty God who has given His blessings to the writer in compiling this bachelor thesis. With passion and desire to add greater insight about Pipe Stress & Heat Transfer Analysis, the writer had compiled this bachelor thesis as one of the requirements in accomplishing the Bachelor's Degree in Engineering (S.T., B.Eng) at the Department of Marine Engineering in Institut Teknologi Sepuluh Nopember (ITS), Surabaya. In addition, the Bachelor Thesis can be used as a study material for students in the Department of Marine Engineering to assist in resolving problems relating to the pipe stress analysis and heat transfer analysis.

The completion of this report cannot be done without the help and support of all the people involved, and the writer humbly thank to:

1. Author's parent, Ingot Pieter Agustin Panggabean and Rinipan, SE., author's siblings, and whole family who have always give motivation and pray;
2. Taufik Fajar Nugroho, S.T., M.Sc., as the first supervisor in this bachelor thesis, who has given knowledge, guidance, suggestions and motivation to the writer;
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9. Big Family of GBI KOG Surabaya and GBI MY HOME Tanjungpinang, who have provided motivations and prayers to the author;
10. All the people who had helped the writer in the compilation of this bachelor thesis.

The writer realizes that this bachelor thesis is far away from perfect. Therefore, The authors expect suggestions and ideas in order to improve this bachelor thesis become a better writing in the future.

May God repay and bless all the good favors that had been granted. It is in the hopes and prayers of the writer that this report can be of great use.

Surabaya, 25 July 2017
Writer

<u>Juda Imanuel Osvaldo Panggabean</u>
NRP. 4213101038

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CHAPTER I
INTRODUCTION

1.1. Background

Piping is a system of pipes used to convey fluids (liquids and gases) from one location to another. Industrial process piping (and accompanying in-line components) can be manufactured from wood, fiberglass, glass, steel, aluminum, plastic, copper, and concrete. In designing of piping, there are some factors that must be considered, such as the fluid characteristics which will flow inside the pipe, location, material used, the standard code of piping, and others.

In designing of piping systems, have been many cases where the pipeline which has designed actually can not withstand the pressure of the fluid that through inside it so that the pipeline eventually experiencing cracks and causing leaks. Therefore, in designing piping system, one of the requirements that must be done is pipe stress analysis.

Pipe stress analysis is conducted with the aim to ensure that the piping system can operate safely without any wreck. Pipe stress analysis can analyze the pipe's material resistance to a fluid flow inside the pipe which can lead to corrosion and crack, can also analyze the pipe's lifetime, and others. Some factors that can affect the pipe's strength are stress, corrosion, and erosion.

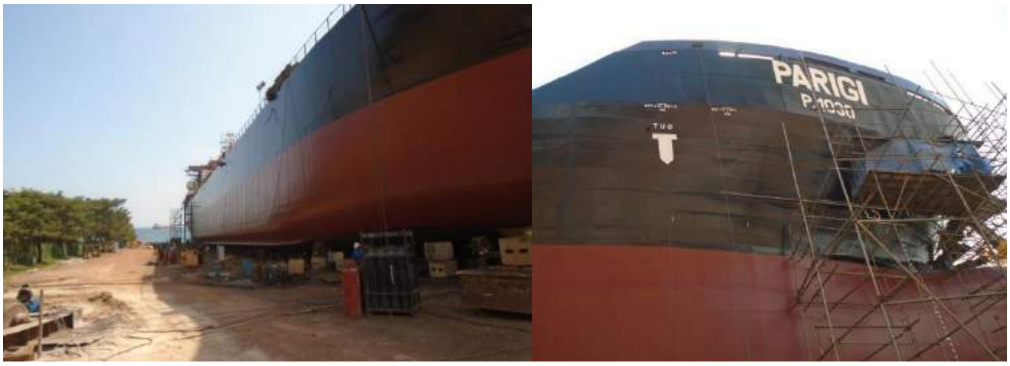

Figure 1.1. 17500 LTDW Product Oil Tanker
Reference: http://www.anggrekhitam.com/product-oil-tanker-pattimura/

The thermal oil system is one of the important systems that installed on the ship. It is used to transfer heat from thermal oil into each fuel tank so that the fuel oil temperature inside the tank can be maintained. This system operates at high temperature, in which if not evaluated can cause damage to existing piping system (for example cracking). Therefore, this bachelor thesis analyzes the strength of thermal oil piping system inside each fuel tank (heating coil), which will be done by using a simulation of software, namely Caesar II. This bachelor thesis also analyzes is the thermal oil piping system able to transfer heat into the fuel oil tanks with the designed value.

In the other word, this bachelor thesis will conduct an engineering evaluation for thermal oil piping system on MT. Parigi. This assessment or evaluation must be done because the current thermal oil piping system that installed on board has not been tested yet, so it does not know whether the piping system can operate safely or not. The evaluation will be done by using two analyses, namely pipe stress analysis, and heat transfer analysis.

1.2. Statement of Problems

Based on the background above, the author will elevate some problems as follow.

1. How much stresses happened and where the stress location is the most critical in the thermal oil piping system?;
2. If condition that was stated on no. 1 occurs, what method will be done to overcome or reduce the critical stress in thermal oil piping system?;
3. Is thermal oil piping system inside the fuel tanks that has been installed onboard able to withstand the pressure and temperature of the fluid (thermal oil) flowing therein (allowable pipe stress is bigger than stresses that happened in the pipe)?;
4. Is thermal oil system that has been installed onboard able to distribute heat into the fuel oil tanks in accordance with the value which has been calculated at the design stage?.

1.3. Research Limitations

To keep this bachelor thesis focus at the problems which are mentioned before, there must be limitations. The limitations are as follow.

1. Analyses are only done on MT. Parigi (17500 LTDW Product Oil Tanker);
2. Just analyze the stress occur in thermal oil piping system (heating coil) and heat transfer of thermal oil on fuel oil tanks.

1.4. Research Objectives

The objectives of writing this bachelor thesis are as follow.

1. To calculate how much stresses happened and find out where the most critical stress location happened in the thermal oil piping system on fuel oil tanks;
2. To identify what method will be done to overcome or reduce the critical stress in thermal oil piping system if there is a critical stress;
3. To identify is the thermal oil piping system inside the fuel tanks that has been installed onboard able to withstand the pressure and temperature of the fluid (thermal oil) flowing therein (allowable pipe stress is bigger than stresses that happened in the pipe);
4. To identify is the thermal oil system that has been installed onboard able to distribute heat into the fuel oil tanks in accordance with the value which has been calculated at the design stage.

1.5. Research Benefits

The benefits of writing this bachelor thesis are as follow.

1. Understand procedures in calculating the stresses happened and in finding out the most critical stress location happened in thermal oil piping system of fuel tanks;
2. Known the method which will used to overcome or reduce the critical stress happened in thermal oil piping system;
3. Conclude is the thermal oil piping system inside the fuel tanks that has been installed onboard able to withstand the pressure and temperature of the fluid (thermal oil) flowing therein (allowable pipe stress is bigger than stresses that happened in the pipe)?;
4. Conclude is the thermal oil system that has been installed onboard able to distribute heat into the fuel oil tanks in accordance with the value which has been calculated at the design stage.

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CHAPTER II
LITERATURE REVIEW

2.1. Overview

In transporting heat onboard, there are three types of heater that commonly used in maritime industry, they are thermal oil heaters, steam heaters, and electrical heaters. Each of this type of heater has advantages and disadvantages, but in producing heat on board without need high operating pressures just thermal oil heaters can do that process.

The 17500 LTDW Product Oil Tanker (MT. Parigi) use the thermal oil system to provide heat to the HFO tanks onboard. The heating process of thermal oil fluid on MT. Parigi is done by boiler and economizer. It will use boiler to heat the fluid when the ship sails in the territorial sea or use power of the main engine below 85% MCR. Meanwhile, economizer will be used when the ship sails at the high sea (minimum use 85% MCR of the main engine). The following figure will show the exhaust gas data of main engine (MAN 6S35MC7.1-TRII with 1 MAN TCR22-21).

Table 2.1. ISO Exhaust Gas Data of Main Engine used on MT. Parigi
Reference: Hitam, Anggrek, Technical Data of Main Engine

Load (%MCR)	Power (kW)	Speed (r/min)	SFOC (g/kWh)	Exh. Gas Amount (kg/h)	Exh. Gas Temp. (°C)
100	4440	173	179	37200	265
95	4218	170.1	178	35900	258
90	3996	167	177.4	34600	253
85	3774	163.9	177.1	33300	249
80	3552	160.6	177	31900	246
75	3330	157.2	177.2	30400	245
70	3108	153.6	177.7	28800	245
65	2886	149.9	178.4	27200	247
60	2664	145.9	179.4	25500	250

Thermal oil plant need supported equipment to distribute heat to the nomination tanks, such as pipes, pumps, valves, pressure indicator, and others. The following figure will show the schematic diagram of thermal oil system on 17500 LTDW Product Oil Tanker.

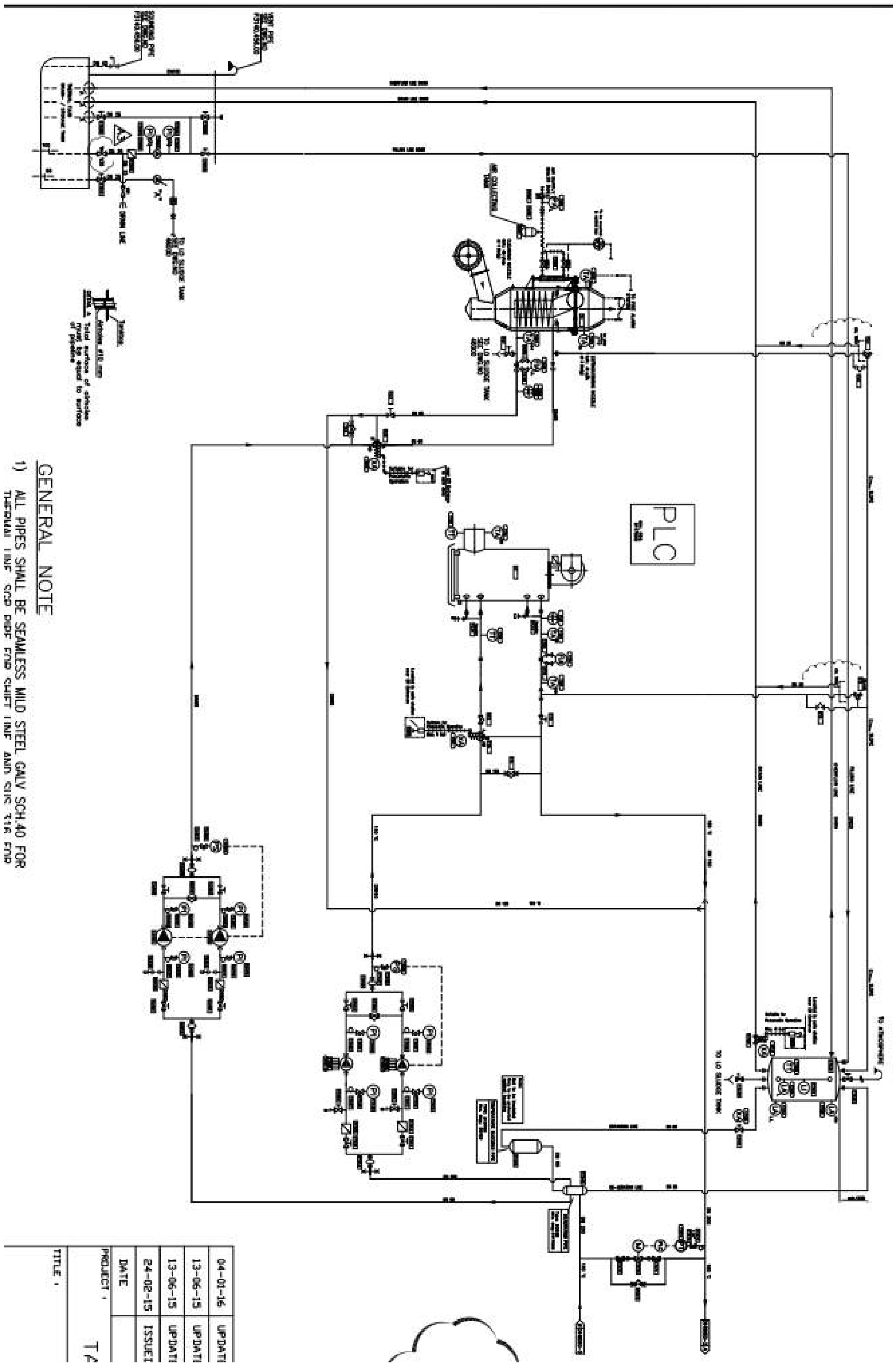


Figure 2.1. Schematic Diagram of Thermal Oil System on 17500 LTDW Product Oil Tanker
Reference: AH 037- 050411- Rev 3- Flow Diagram Thermal Oil Main System

Thermal oil system can be operated in high temperatures operation, up to 300^oC. So, the supported equipment of this system must be able to withstand in that temperatures, if not, the equipment will become expanded because of the presence of thermal stress. One of the main components that must be ensured can withstand in that temperature is the piping system.

The thermal oil piping system has been installed onboard, but the system has not been tested yet so that it does not know whether the system can operate safely or not. If the piping system used is not able to withstand in that temperature, then there must be a leakage in the thermal oil distribution process. If the piping system used is able to withstand the pressure and temperature of the thermal oil fluid, then the system also must be ensured that heat requirements of tanks onboard must be achieved in accordance with the designed value.

2.2. Basic Theories

2.2.1. Piping Codes Standard

In designing the piping system, the designer must consider two factors in such planning, first is feasibility factors piping system design in terms of technical and second is the feasibility factors piping system in term of economic. The feasibility factors piping system design in terms of technical can be derived from doing some analysis, such as piping stress analysis, but the feasibility factors in term of economy depend on the financial policy of a company or industry which is based on codes.

The piping code is a set of minimum requirements used to ensure that the plants built accordingly are safe and it specifies the permissible materials, acceptable designs and fabrications, and the inspection requirements and procedures (Liang-Chuan , Tsen-Loong, 2009). Today, almost all companies are using codes for their piping system. The roles of codes and standards will be shown in figure 2.3. below.

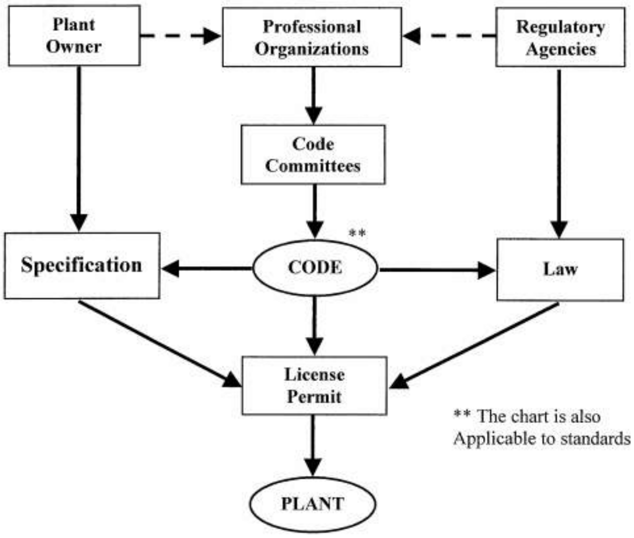


Figure 2.2. Roles of Codes and Standards
Reference: Chuan & Loong (2009), Pipe Stress Engineering Chapter I, Page 20

Actually, the codes are a stand-alone document with no enforcing power, but if the codes are adopted by the regulatory agencies, the codes will become a part of the law as shown in figure 2.2. above. Nowadays, many companies have adopted the piping codes as their requirement in constructing a plant and also the codes must be included in a contract. So, if one of the contract parties does not follow the standards or codes, then that party will be fined and could be reported by law.

Today, there are some piping codes used by companies or industries, are as follows.

1. ASME B31.1, Power Piping;
2. ASME B31.3, Process Piping;
3. ASME B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids;
4. ASME B31.5, Refrigeration Piping, and Heat Exchanger Components;
5. ASME B31.8, Gas Transmission, and Distribution Piping Systems;
6. ClassNK Rules Part D Machinery Installations and Part K Materials.

2.2.2. Classification of Loads in Piping System

In designing the pipeline path must consider loads that may be happened to the pipelines so that they are significant to the proposed plant and applicable to the proposed installation and operation. Loads in pipelines may cause or induce failure to the pipeline or loss of reliability of the pipeline system so loads must be identified and accounted for design processes. In designing strength of the pipe, loads can be classified as follows.

1) Sustained Loads;
2) Occasional Loads;
3) Construction Loads;
4) Transient Loads.

2.2.2.1. Sustained Loads

Sustained loads are arising from the intended use of the pipeline system and loads from other sources. The weight of the pipeline, including components, fluids, and slurries, and loads due to pressure are examples of sustained loads. In all of the piping system, a pipe is designed to be able to withstand weight loads of fluid, insulation, components, and structure of the pipe itself. The following are some components that include to the sustained loads.

a) Internal Design Pressure;
b) External Hydrostatic Pressure;
c) Weight Effects;
d) Residual Loads;
e) Subsidence.

2.2.2.2. Occasional Loads

Occasional loads are loads that occur "sometimes" in the piping system during the normal operation. Occasional loads can also call as loads which are applied to a system during the only small portion (typically 1 to 10 percent) of the plant's operating life. There are several things that can cause occasional loads, namely.

a) Earthquakes;
b) Wind and Ice loads;
c) Road and rail traffic;
d) Vibration;
e) Waves and currents;
f) Temperature effects.

2.2.2.3. Construction Loads

Construction loads are loads that necessary for the installation and pressure testing of the pipeline system. Construction loads can be divided into 2 groups as follows.

a) Installation loads
   The installation loads are induced during transportation, handling, storage, and lowering-in shall be considered.

b) Hydrostatic testing
   This kind of load is happened when the piping system is in hydrostatic testing process. These loads include weight of contents, thermal, and pressured end effect.

2.2.2.4. Transient Loads

Transient load means as loads that occur in pipeline operation, for example, fire, impact, falling objects, and transient conditions (accidental overpressure, equipment collisions, and others).

2.2.3. Stresses in Piping System

There are some stresses that occurred in the piping system during the operation. These stresses must be considered so that there is no any incident happened when the piping is under operation. It means that the value of total stress that occurred in a piping system must lower than the value of maximum allowable stress from the piping material properties.

Stresses in the piping system can be divided into four categories, namely stress from internal pressure (circumferential or hoop stress), longitudinal stress, stress from thermal expansion, and radial stress.

2.2.3.1. Stress from Internal Pressure

Circumferential (hoop) stress is a stress in a pipe wall. It is represented by the forces inside the cylinder acting towards the circumference perpendicular to the length of the pipe. The effect of this stress has split the pipe into two halves as shown in figure 2.3. below.

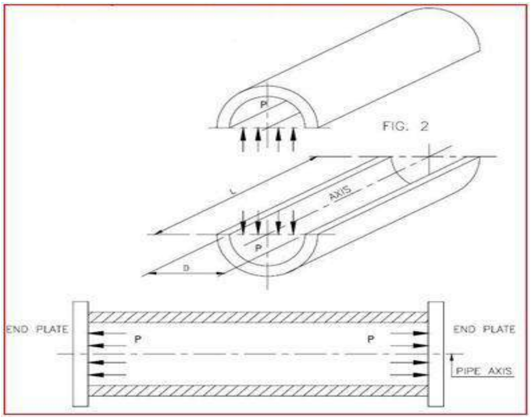


Figure 2.3. Circumferential (Hoop) Stress
Reference: http://www.piping-engineering.com/induced-stresses-in-pipe.html

For both restrained and unrestrained pipelines, the circumferential (hoop) stress due to internal pressure can be calculated as following formula.

$$S_H = \frac{Pi \ x \ D}{2t} \tag{2.1}$$

Reference: ASME B31.4. 2016, Page 13

Where: D = Outside diameter of pipe, in (mm)
Pi = Internal design gage pressure, psi (bar)
S_H = Circumferential (hoop) stress due to internal pressure, psi (MPa)
t = Wall thickness of pipe, in (mm)

2.2.3.2. Stress from Thermal Expansion

Stress from thermal expansion can occur because of the fluid temperature flowing therein pipe and also can occur because of the radiation heat from the piping system environment. This kind of stress could expand the length of pipe.

a) Restrained pipe, can be calculated as following formula.

$$S_E = E\alpha(T_1 - T_2) \tag{2.2}$$

Reference: ASME B31.4. 2016, Page 13

Where: E = Modulus of elasticity
S_E = Thermal expansion stress, psi (MPa)
T_1 = Temperature of the pipe at installation, ^{o}F (^{o}C)

T_2 = Operating temperature, °F (°C)
α = Coefficient of thermal expansion, in./in./°F (mm/mm/°C)

b) Unrestrained pipe, can be calculated as following formula.

$$S_E = \sqrt{S_b^2 + 4S_t^2} \tag{2.3}$$

Reference: ASME B31.4. 2016, Page 17

Where: S_b = Resultant bending stress, psi (MPa), with formula.

$$S_b = \sqrt{(i_i M_i)^2 + (i_o M_o)^2}/Z \tag{2.4}$$

Reference: ASME B31.4. 2016, Page 17

i_i = In-plane stress intensification factor from Table 402.1-1.
i_o = Out-plane stress intensification factor from Table 402.1-1.
M_i = In-plane bending moment, in.-lb (Nm)
M_o = Out-plane bending moment, in.-lb (Nm)
Z = Section modulus of the pipe as applicable, in.^{3} (cm^3)
S_t = Torsional stress, psi (MPa), with formula.

$$S_t = \frac{M_t}{2Z} \tag{2.5}$$

Reference: ASME B31.4. 2016, Page 17

M_t = Torsional moment, in.-lb (Nm)

2.2.3.3. Longitudinal Stress

Longitudinal stress is the stress in a pipe wall, acting along the longitudinal axis of the pipe and produced by the pressure of the fluid in the pipe. The following figure will show the longitudinal stress that happened in the pipe.

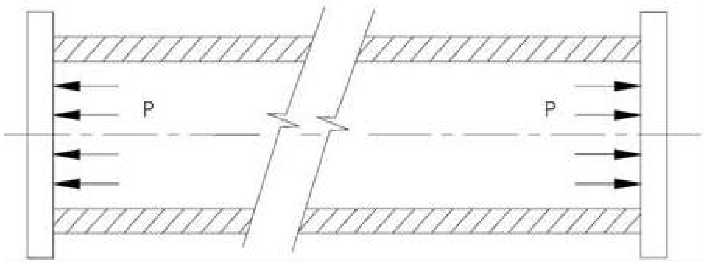


Figure 2.4. Longitudinal Stress in Pipe
Reference: http://www.piping-engineering.com/induced-stresses-in-pipe.html

There are two kind formulas to calculate the value of longitudinal stress as following.

a) Restrained pipe, longitudinal stress in a restrained pipe can be calculated as following formula.

$$S_L = S_E + \vartheta S_H + \frac{M}{Z} + F_a/A \quad (2.6)$$

Reference: ASME B31.4. 2016, Page 17

Where:
- A = Metal area of nominal pipe cross section, in.^{2} (cm^2)
- Fa = Axial force, such as weight on a riser, lb (N)
- M = Bending moment, in.-lb (Nm)
- S_E = Thermal expansion stress, psi (MPa)
- S_H = Circumferential stress due to internal pressure, psi (MPa)
- Z = Section modulus of the pipe, in.^{3} (cm^3)
- ϑ = Poisson's ratio

b) Unrestrained pipe, longitudinal stress in a unrestrained pipe can be calculated as following formula.

$$S_L = \frac{P_i D}{40t} + \frac{iM}{Z} + \frac{F_a}{A} \quad (2.7)$$

Reference: ASME B31.4. 2016, Page 17

Where:
- A = Metal area of nominal pipe cross section, in.^{2} (cm^2)
- D = Outside diameter of pipe, in. (mm)
- Fa = Axial force, such as weight on a riser, lb (N)
- i = Component stress intensification in plane of loading
  = For straight pipe, i = 1.0
- M = Bending moment, in.-lb (Nm)

Pi = Internal design gage pressure, psi (bar)
t = Wall thickness of pipe, in. (mm)
Z = Section modulus of the pipe, in.^{3} (cm^3)

2.2.4. Strength of Materials

The pipe will fail when the total stress that happened in its system bigger than its strength, it means that the maximum allowable stress value of pipe must be bigger than the total stress in its system. That is the definition of strength of the material. The figure 2.5. below will show the characteristic of materials.

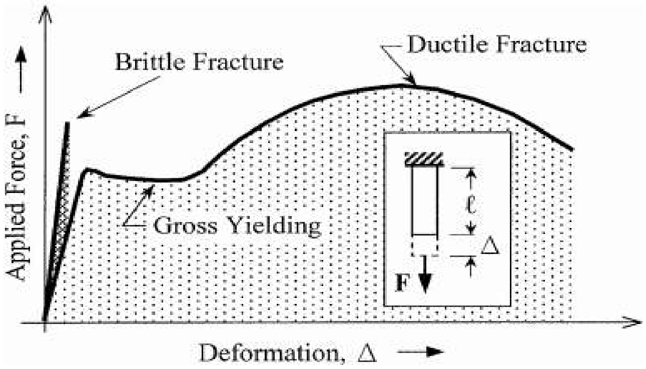


Figure 2.5. Material Characteristics
Reference: Chuan & Loong (2009), Pipe Stress Engineering, Chapter I, Page 9

In general, rupture of material can be classified into two categories, named ductile rupture and brittle rupture.

a) Ductile Rupture

   In ductile rupture, as the load (applied force, F) increases, the material will be experienced yields first producing a considerable plastic deformation and will fail after going through an approximately large amount of elongation or contraction. A ductile piping material elongates about 25% (one-fourth of the original length) before the failure (Liang-Chuan , Tsen-Loong, 2009). The ductile piping material also has a very large energy absorbing capacity. The following figure will show a kind of example of ductile rupture.

Figure 2.6. Ductile Rupture
Reference: Callister & Rethwisch, Material Science & Engineering, 8th Edition, Chapter 8, Page 238

b) Brittle Rupture

In brittle rupture, the pipe does not experience yield or does not produce plastic deformation, which is has a very small capacity in absorbing energy. This kind of rupture often occurs unexpectedly and suddenly. Materials which have characteristic like this can not be used in the environment with either thermal or mechanical shock loading. The figure below will show a kind of example of brittle rupture.

Figure 2.7. Brittle Rupture
Reference: Callister & Rethwisch, Material Science & Engineering, 8th Edition, Chapter 8, Page 238

Some materials can become brittle because of temperature change. Most piping materials lose their ductility as the temperature drops below a certain limit, for example, most carbon steels are susceptible to brittle failure at temperatures lower than -20°F (-29°C), whereas other materials (e.g., austenitic stainless steel, aluminum, copper, and brass) do not become brittle at temperatures as low as -425°F or -254°C (Liang-Chuan , Tsen-Loong, 2009). Some materials can also become brittle at high temperature due to metallurgical change, such as mild carbon steel may lose its ductility at temperatures above 800°F (427°C) due to its susceptibility to graphite formation (Chuan & Loong, 2009).

At high-temperature environment, the pipe will continue to deform under sustained stress. The pipe may fail after a certain period even if the stress which occurred on the pipe is much lower than the ultimate strength material of the pipe, which is called as creep rupture phenomenon. The figure 2.8. below will show the relation between temperature and allowable stress of some pipe materials.

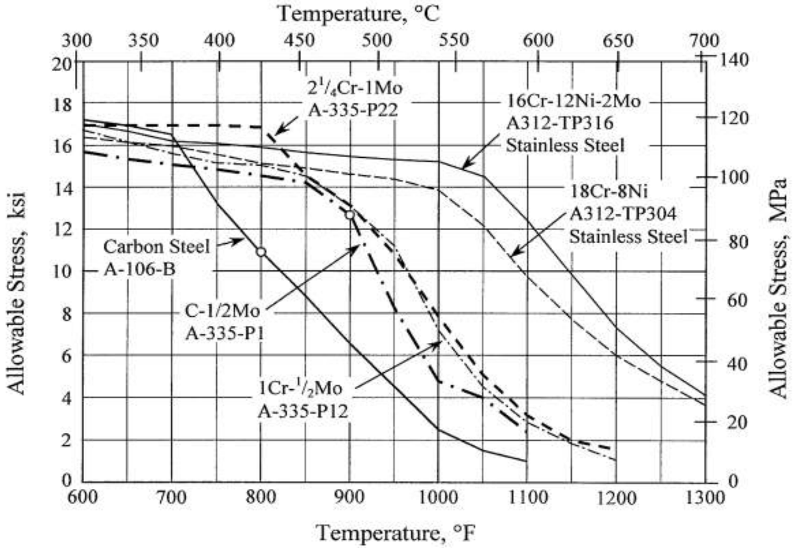


Figure 2.8. Allowable Stress at High Temperature
Reference: Chuan & Loong (2009), Pipe Stress Engineering, Chapter I, Page 16

From the figure 2.8. above, it can be concluded that the allowable stress of some materials are dropped sharply after the temperature reaches a certain point. This is mainly due to transition from the static failure to creep failure at high temperature. Therefore, the environment temperature becomes one important thing that must be considered by piping engineer in designing the piping system.

2.2.5. Heat Transfer

In transferring heat, there are three modes of heat transfer, they are conduction, convection, and radiation.

a) Conduction

Conduction is the heat transfer process that will occur across the medium. It means that the process of transfer energy is coming from more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between particles. The rate of heat conduction depends on geometry, thickness, material, and temperature difference.

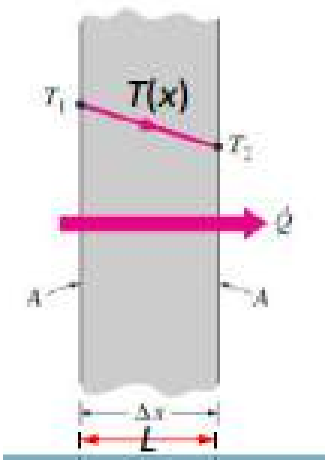


Figure 2.9. Heat Conduction Process

Reference: Fitri, Sutopo P. (2014), Heat Transfer Modes, Page 8

To quantify the conduction heat transfer processes can be done by using the formula of Fourier's Law (1822), as follows.

$$q = -k \frac{dT}{dx} \quad (2.8)$$

Reference: Lienhard IV & V (2010), A Heat Transfer Textbook, 4th Edition, Chapter 1, Page 10

Where: q = Heat flux, W/m^2
K = Thermal conductivity, W/m.K
dT/dx = Temperature gradient, K/m

b) Convection

Convection is the mode of energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion.

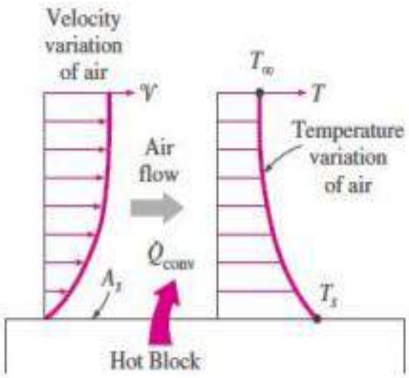


Figure 2.10. Heat Convection Process
Reference: Fitri, Sutopo P. (2014), Heat Transfer Modes, Page 14

There are two kinds of convection heat process, they are natural or free convection and forced convection. Natural or free convection means that the fluid motion which is caused by the buoyancy forces that are induced by density differences due to the variation of temperature in the fluid. Meanwhile forced convection means that the fluid is forced to flow over the surface by external equipment, such as a fan.

In calculating the rate of convection heat transfer, it uses Newton's Law, which states that the rate of convection heat transfer is proportional to the temperature difference. The following is the formula that used in calculating the rate of convection heat transfer.

$$q = h\,(T_s - T_\infty) \tag{2.9}$$

Reference: Lienhard IV & V (2010), A Heat Transfer Textbook, 4th Edition, Chapter 1, Page 19

Where: q = Heat flux, W/m^2
h = Convection heat transfer coefficient, $W/m^2.K$

Table 2.2. Typical Values of Convection Heat Transfer Coefficient
Reference: Fitri, Sutopo P. (2014), Heat Transfer Modes, Page 17

Type of Convection	**h ($W/m_2.^oC$)**
Free convection of gases	2-25
Free convection of liquids	10-1000
Forced convection of gases	25-250
Forced convection of liquids	50-20000
Boiling and condensation	2500-100000

T_s = Surface Temperature, K
T_∞ = Fluid Temperature, K

c) Radiation

The radiation heat transfer process is transported by the electromagnetic waves (or photons) as a result of the changes in the electronic configurations of the atoms or molecules. The net rate of radiation heat transfer can be calculated by using following formula.

$$q_{rad} = \varepsilon\ \sigma\ (T_s^4 - T_{sur}^4) \tag{2.10}$$

Reference: Fitri, Sutopo P. (2014), Heat Transfer Modes, Page 22

Where: q_{rad} = Heat flux, W/m^2
ε = Emmisivity, $0 \leq \varepsilon \leq 1$, $W/m^2.K$
σ = Stefan-Boltzmann constant, 5,67 x 10^{-8} $W/m^2.K^4$
T_s = Surface temperature, K
T_∞ = Fluid temperature, K

The total rate of heat transfer by simultaneously convection process can be calculated as following formula.

$$\begin{aligned} q &= qconv + qrad \\ &= h\ (T_s - T_\infty) + \ \varepsilon\sigma(T_s^4 - T_{sur}^4) \end{aligned} \tag{2.11}$$

Reference: Fitri, Sutopo P. (2014), Heat Transfer Modes, Page 24

The heat transfer modes also can analyze by using the equation of heat flow which is analogous to the relation of electric current flow which will show in the figure 2.11. below.

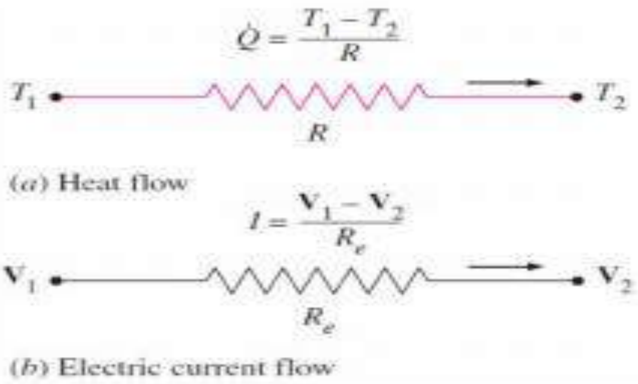


Figure 2.11. Analogy Relation of Electric Current Flow with Heat Flow
Reference: Fitri, Sutopo P. (2014), Conduction Heat Transfer, Page 13

So, in calculating the heat transfer modes (conduction, convection, and radiation) flow in a system, it can be done by using thermal resistance network formula as follow.

$$Q = \frac{T_{\infty_1} - T_{\infty_2}}{R_{total}} \tag{2.12}$$

Source: Fitri, Sutopo P. (2014), Conduction Heat Transfer, Page 16

Where:
- Q = Heat capacity, W
- $T_{\infty1}$ = Fluid temperature in Area 1, K
- $T_{\infty2}$ = Fluid temperature in Area 2, K
- R_{total} = Total resistance, K/W

The following figure is an example in calculating total resistance of thermal resistance network equation.

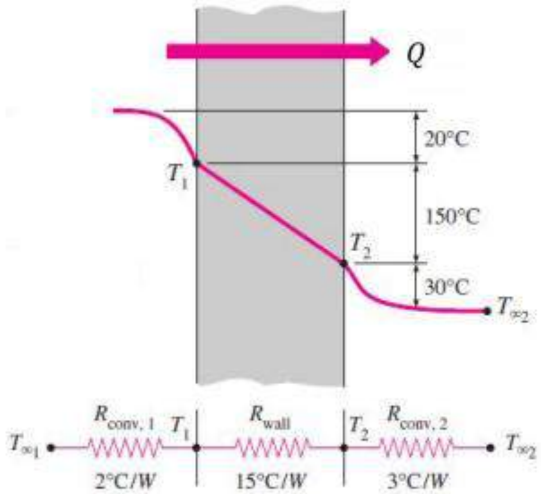


Figure 2.12. Thermal Resistance Network
Source: Fitri, Sutopo P. (2014), Conduction Heat Transfer, Page 15

From the figure 2.12. above, the total resistance formula can be arranged as following formula.

$$R_{total} = R_{conv,1} + R_{wall} + R_{conv,2} = \frac{1}{h_1 A} + \frac{L}{KA} + \frac{1}{h_2 A} \tag{2.13}$$

Reference: Fitri, Sutopo P. (2014), Conduction Heat Transfer, Page 16

In calculating heat transfer, there is also a formula named Heat Balance Formula. It is intended to compare the heat received and expended in various thermal processes.

$$Qin = Qout = m \times Cp \times \Delta T \tag{2.14}$$

Reference: https://mheyong.files.wordpress.com/2010/06/kalor.pdf

Where: Q = Heat capacity, kW
m = Mass flow rate, kg/s
ΔT = Temperature difference, K (°C)
Cp = Specific heat, kJ/kg°C
= for Exhaust Gas as following table

Table 2.3. Specific Heat Data of Exhaust Gas
Reference: https://www.dieselnet.com/tech/diesel_exh.php

Temperature (K)	Density (kg/m³)	Enthalpy (kJ/kg)	Entropy (kJ/kgK)	Specific Heat (kJ/kgK)	Thermal Conductivity (W/mK)
260	1,34	260	6,727	1,006	0,0231
280	1,245	280,2	6,802	1,006	0,0247
300	1,161	300,3	6,871	1,007	0,0263
350	0,995	350,7	7,026	1,009	0,0301
400	0,871	401,2	7,161	1,014	0,0336
450	0,774	452,1	7,282	1,021	0,0371
500	0,696	503,4	7,389	1,030	0,0404
600	0,58	607,5	7,579	1,051	0,0466
800	0,435	822,5	7,888	1,099	0,0577
1000	0,348	1046,8	8,138	1,141	0,0681
1200	0,290	1278	8,349	1,175	0,0783
1400	0,249	1515	8,531	1,207	0,0927

2.2.6. Exhaust Gas Flow Rate

In this bachelor thesis will use maker's formula in order to calculate the flow rate of exhaust gas of diesel engine on MT. Parigi. The formula is as follow.

$$M_{Exh} = M_{L1} \text{ x } \frac{P_M}{P_{L1}} \text{ x } \left\{1 + \frac{\Delta m_{M\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta M_{amb\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta m_{s\%}}{100}\right\} \text{ x } \frac{P_{s\%}}{100} \tag{2.15}$$

Reference: B&W, MAN. (2010), MAN B&W S35MC7-TII Project Guide Camshaft Controlled Two Stroke Engines, Section 6.04, Page 8

Where: M_{Exh} = Exhaust gas amount to be found, kg/h
M_{L1} = Exhaust gas amount at nominal, kg/h
P_M = Power at SMCR point, kW
P_{L1} = Power at desired value, kW
$\Delta m_{M\%}$ = Specific gas amount at nominal MCR, %
= Can be found by using following formula.

$$\Delta m_{M\%} = (14 \text{ x } \ln (P_M/P_{L1})) - (24 \text{ x } \ln (n_M/n_{L1})) \tag{2.16}$$

Reference: B&W, MAN. (2010), MAN B&W S35MC7-TII Project Guide Camshaft Controlled Two Stroke Engines, Section 6.04, Page 9

$\Delta M_{amb\%}$ = Change in exhaust gas amount, %
= Can be found by using following formula.

$$\Delta M_{amb\%} = -0{,}41 \text{ x } (T_{air} - 25) + (\rho_{bar} - 1000) + 0{,}19 \text{ x } (T_{CW} - 25) - 0{,}011 \text{ x } (\Delta p_M - 300)$$
(2.17)

Reference: B&W, MAN. (2010), MAN B&W S35MC7-TII Project Guide Camshaft Controlled Two Stroke Engines, Section 6.04, Page 10

$P_{s\%}$ = Continuous service rating of engine, kW
= Can be found by using following formula.

$$P_{s\%} = (P_s/P_M) \text{ x } 100\%$$
(2.18)

Reference: B&W, MAN. (2010), MAN B&W S35MC7-TII Project Guide Camshaft Controlled Two Stroke Engines, Section 6.04, Page 10

$\Delta M_{s\%}$ = Specific gas amount at MCR point, %
= Can be defined by using following formula.

$$\Delta m_{s\%} = 37 \text{ x } ({}^{P_S}/_{P_M})^3 - 87 \text{ x } ({}^{P_S}/_{P_M})^2 + 31 \text{ x } \left({}^{P_S}/_{P_M}\right) + 19$$
(2.19)

Reference: B&W, MAN. (2010), MAN B&W S35MC7-TII Project Guide Camshaft Controlled Two Stroke Engines, Section 6.04, Page 10

2.3. Data Collection of Bachelor Thesis

2.3.1. Shop Trial Record of Main Engine

MT. Parigi uses diesel engine as its main propulsion. The type of the main engine is STX 6S35MC7 with turbocharger type is TCR22-21075. The following table will show the result of shop trial record of the main engine.

Table 2.4. Shop Trial Record of Diesel Engine on MT. Parigi
Reference: Hitam, Anggrek. (2014), Shop Trial Record of Diesel Engine

Load (%)	Engine Speed (rpm)	Engine Output (kW)	Specific Fuel Consumption (g/kWh)	Fuel Consumption (kg/h)	Exhaust T/C Inlet (°C)	Exhaust T/C Outlet (°C)
110	178,6	4884	185,52	907,6	455	265
100	173	4440	186,39	827,6	420	240
85	163,9	3774	184,86	800	380	225
75	157,2	3330	185,68	618,3	365	225
50	137,3	2220	195,77	434,6	385	240
25	109	1110	204,84	227,4	290	240

2.3.2. Technical Data of Economizer

Economizer on MT. Parigi will be used to heat the thermal oil fluid. It is used when the ship sails at high sea (minimum 85% MCR). The following table will show the technical data of economizer.

Table 2.5. Technical Data of Economizer
Reference: Hitam, Anggrek, Technical Data of Thermal Oil Heater

Technical Data of Economizer	
Type	Aalborg EXV632 46 48.3 900DD
Quantity	23,7 m^3/h
Inlet Temperature	140^oC
Outlet Tempearature	180^oC
Flow Resistance	17,5 m.l.c
Diameter Without Insulation	1664 mm
Weight (Empty)	6200 kg
Liquid Contents	1190 Litres

2.3.3. Thermal Oil Fluid Specification

From the shipyard, it is said that the thermal oil fluid which will be used in the plant is not specified yet. In the catalog of thermal oil heater from Alfa Laval, there is some kind of thermal oil fluid which is recommended by the manufacturer. One of them is Therminol 66 with the following specification.

Table 2.6. Thermal Oil Fluid Specification
Reference: Solutia, High Performance Highly Stable Heat Transfer Fluid

Specification of Thermal Oi Fluid	
Type	Therminol 66
Composition	Hydrogenated Terphenyl
Kinematic Viscosity (40^oC)	29,64 cSt
Density (15^oC)	1011 kg/m^3
Flash Point	170 ^oC
Fire Point	216 ^oC
Total Acidity	<0,02 mgKOH/g
Pour Point	-32 ^oC

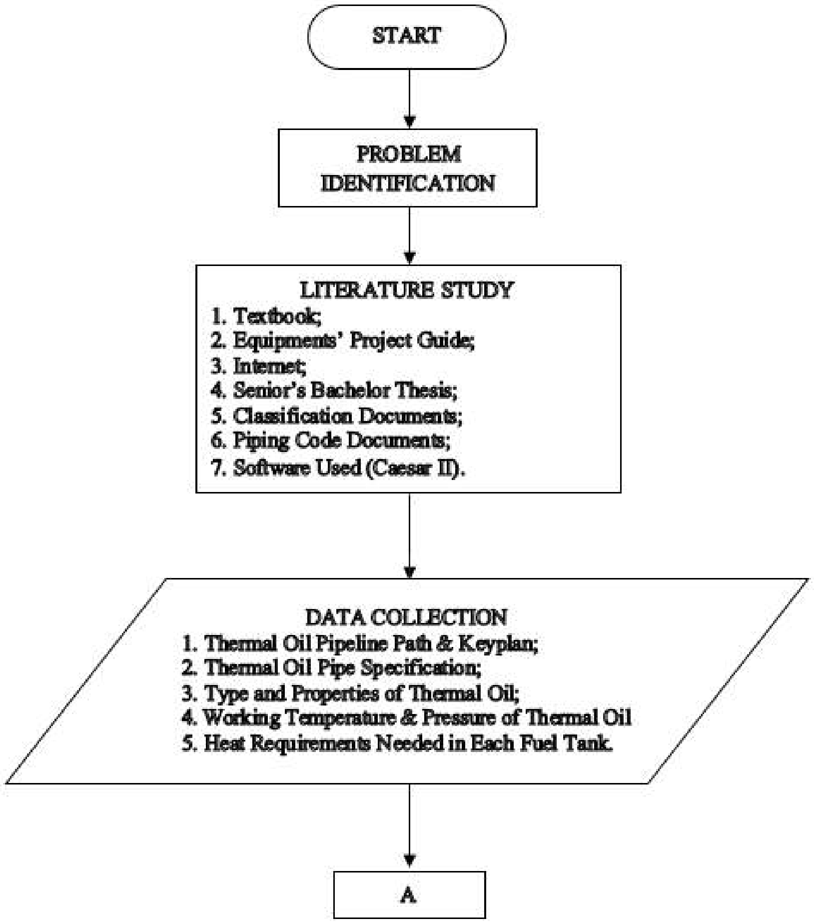
CHAPTER III
METHODOLOGY

3.1. General

The methodology is procedures or principles that arranged in a process diagram in solving some problems. In each step of the methodology, there must be an explanation about the step itself. Commonly, the methodology is presented by using a flowchart. So, the author will conduct the bachelor thesis in accordance with the methodology flowchart that has been made.

3.2. Methodology Flow Chart

The following methodology flowchart will show the process diagram in conducting the bachelor thesis.



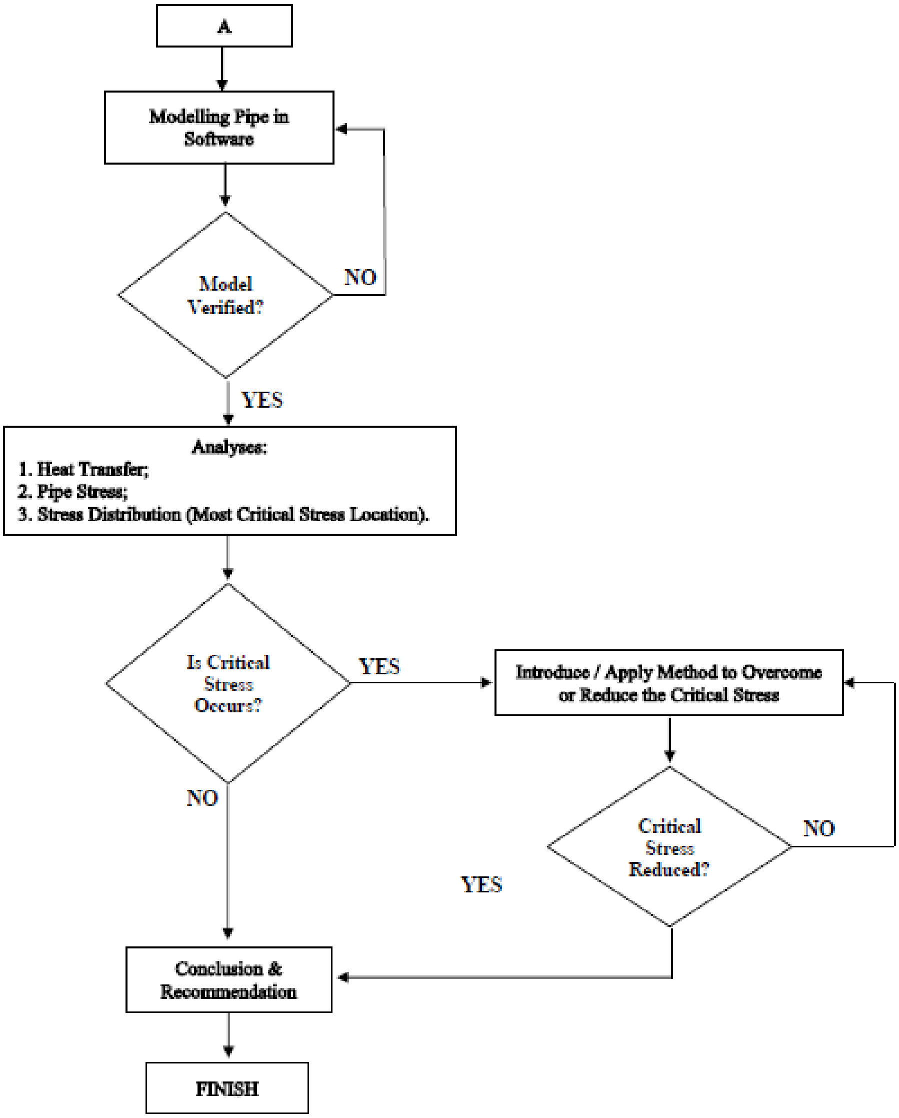


Figure 3.1. Methodology Flowchart of Bachelor Thesis

3.3. Bachelor Thesis Methodology

The methodology used in conducting the Bachelor thesis process will be explained as follows.

3.3.1. Problem Identification

The writing of this bachelor thesis is started by identifying the problems, it means that the author must look for the problems. In conducting this step use a question, “Why do the Problem Exist?”. The purpose of this activity is to simplify the problems which will be discussed in this bachelor thesis.

3.3.2. Literature Study

Literatures study means the sources that the author took from, or it is commonly said references. In compiling this bachelor thesis, the author needs some references or literature about the pipe stress analysis, piping codes, schematic diagram of the thermal oil system, specification of equipment that used in the thermal oil system, heat transfer data, and others. These literature are obtained from:

- Textbook;
- Equipment’s Project Guide;
- Internet;
- Senior’s Bachelor Thesis;
- Classification Documents;
- Piping Code Documents;
- Software Used (Caesar II).

3.3.3. Data Collection

Data collection means that all data that needed in conducting the bachelor thesis. In this bachelor thesis, data needed are as follows.

- Thermal Oil Pipeline Path & Keyplan;
- Thermal Oil Pipe Specification;
- Type and Properties of Thermal Oil;
- Working Temperature & Pressure of Thermal Oil;
- Heat Requirements Needed in Each Fuel Tank.

3.3.4. Modeling System in Software

Input data from the previous process will be used in modeling thermal oil piping system into the software. The software used are intended to make a calculation for the pipe stress analysis. Software that used in this bachelor thesis is Caesar II. In modeling the thermal oil piping system into the software, there must be a verification process to ensure that the input parameters are already appropriate with the real condition of the pipe data or not.

3.3.5. Modeling Verification

Modeling verification means that the piping input parameter in the software must be in accordance with the real condition of the pipe. If the input parameter is already appropriate for the real condition, the modeling pipe will be run and will be known later the result of the pipe stress including the stress analysis report.

After verifying, software used will show a sketch that represents the real condition of thermal oil piping system which will be analyzed later.

3.3.6. Analyses

Analyses which are conducted in this bachelor thesis are as follow.

- Heat transfer analysis, it means that the heat distribution in thermal oil system onboard will be analyzed. The output value from this step is known whether the heat which is distributed from thermal oil system (boiler and economizer) to the fuel oil tanks (storage tanks, settling tank, and service tanks) is already appropriate for the designed value or not.
- Pipe stress analysis, it means to stress that happened at thermal oil pipes will be analyzed. Output value from this step is known whether the pipes used in thermal oil system can withstand the pressure and temperature of working fluid therein. In the other words, the maximum allowable stress value of pipes' material must be higher than the total stress value that happened at the pipes.
- Stress distribution, this step is intended to find out where the most critical stress location happened in thermal oil piping system onboard. Output values from this step are known the most critical stress location and actions to be done to overcome the critical stress in thermal oil piping system.

3.3.7. Conclusion & Recommendation

The expected conclusions from this bachelor thesis are thermal oil pipes that have been installed onboard able to withstand the pressure and temperature by thermal oil fluid therein and the system can distribute heat to the fuel oil tanks in accordance with the designed value before.

CHAPTER IV
DATA ANALYSIS

4.1. Heat Transfer Analysis

As you can observe, the technical data of exhaust gas of the main engine based on ISO condition (Table 2.1.) with shop trial record (Table 2.4.) is different. Moreover, the flow rate of exhaust gas in shop trial record is not measured so that it must be defined first. Then, will be determined whether the economizer is able to heat the thermal oil fluid or not, and will calculate the heat losses happened along the distribution line into the fuel oil tanks.

4.1.1. Exhaust Gas Flow Rate

The exhaust gas flow rate of diesel engine used on MT. Parigi based on shop trial record at 75%, 85%, and 100% MCR will be calculated by using formula 2.15.

4.1.1.1. Exhaust Gas Amount at 75% MCR of Diesel Engine

The value of exhaust gas amount at 75% MCR of diesel engine used on MT. Parigi can be calculated as follows.

$$M_{Exh} \quad = M_{L1} \text{ x } \frac{P_M}{P_{L1}} \text{ x } \left\{1 + \frac{\Delta m_{M\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta M_{amb\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta m_{s\%}}{100}\right\} \text{ x } \frac{P_{s\%}}{100}$$

Where:

M_{L1}	= 37200		kg/h
P_M	= 3330		kW
P_{L1}	= 4440		kW
$\Delta m_{M\%}$	= By using formula 2.16., the value is		
	= -1,729		%
$\Delta m_{amb\%}$	= By using formula 2.17., the value is		
	= -3,249		%
$\Delta m_{s\%}$	= By using formula 2.19., the value is		
	= 8,922		%
$P_{s\%}$	= By using formula 2.18., the value is		
	= 75		%

With the known data above, the value of exhaust gas flow rate is as follows.

$$M_{Exh\ 75\%MCR} \qquad = 21670 \qquad \text{kg/h}$$

Based on the calculation above, it is known that the exhaust gas amount of diesel engine at 75% MCR is 21670 kg/h.

4.1.1.2. Exhaust Gas Amount at 85% MCR of Diesel Engine

The value of exhaust gas amount at 85% MCR of diesel engine used on MT. Parigi can be calculated as follows.

$$M_{Exh} \quad = M_{L1} \text{ x } \frac{P_M}{P_{L1}} \text{ x } \left\{1 + \frac{\Delta m_{M\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta M_{amb\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta m_{s\%}}{100}\right\} \text{ x } \frac{P_{s\%}}{100}$$

Where:	$M_{L1'}$	= 37200	kg/h
	P_M	= 3774	kW
	P_{L1}	= 4440	kW
	$\Delta m_{M\%}$	= By using formula 2.16., the value is	
		= -0,978	%
	$\Delta m_{amb\%}$	= By using formula 2.17., the value is	
		= -4,069	%
	$\Delta m_{s\%}$	= By using formula 2.19., the value is	
		= 5,215	%
	$P_{s\%}$	= By using formula 2.18., the value is	
		= 85	%

With the known data above, the value of exhaust gas flow rate is as follows.

$$M_{Exh\ 75\%MCR} \quad = 26862 \quad \text{kg/h}$$

Based on the calculation above, it is known that the exhaust gas amount of diesel engine at 85% MCR is 26862 kg/h.

4.1.1.3. Exhaust Gas Amount at 100% MCR of Diesel Engine

The value of exhaust gas amount at 100% MCR of diesel engine used on MT. Parigi can be calculated as follows.

$$M_{Exh} \quad = M_{L1} \text{ x } \frac{P_M}{P_{L1}} \text{ x } \left\{1 + \frac{\Delta m_{M\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta M_{amb\%}}{100}\right\} \text{ x } \left\{1 + \frac{\Delta m_{s\%}}{100}\right\} \text{ x } \frac{P_{s\%}}{100}$$

Where:	$M_{L1'}$	= 37200	kg/h
	P_M	= 4440	kW
	P_{L1}	= 4440	kW

$\Delta m_{M\%}$ = By using formula 2.16., the value is
= 0 %
$\Delta m_{amb\%}$ = By using formula 2.17., the value is
= -3,789 %
$\Delta m_{s\%}$ = By using formula 2.19., the value is
= 0 %
$P_{s\%}$ = By using formula 2.18., the value is
= 100 %

With the known data above, the value of exhaust gas flow rate is as follows.

$$M_{Exh\ 100\%MCR} = 35757 \quad kg/h$$

Based on the calculation above, it is known that the exhaust gas amount of diesel engine at 100% MCR is 35757 kg/h.

4.1.1.4. Summary of Exhaust Gas Amount

The following table will show the summary of exhaust gas amount in certain load condition based on the calculation above.

Table 4.1. Exhaust Gas Amount Based on Maker's Formula

Load (%)	Engine Speed (rpm)	Engine Output (kW)	Exhaust T/C Inlet (°C)	Exhaust T/C Outlet (°C)	Exhaust Gas Amount (kg/h)
100	173	4440	420	240	35757
85	163,9	3774	380	225	26862
75	157,2	3330	365	225	21670

4.1.2. Economizer Analysis

Economizer analysis is because there are differences data between maker's document with shop test of the main engine which will be shown as the following table.

Table 4.2. Exhaust Gas Parameter Comparison between Maker's and Shop Test Data

	Maker's Data			**Shop Trial Record Data**	
Load (%)	**Exh. Gas Quantity (kg/h)**	**Exh. Gas Temp. Before Heater (°C)**	**Exh. Gas Temp. After Heater (°C)**	**Exh. Gas Quantity (kg/h)**	**Exh. Gas Temp. Before Heater (°C)**
100	37200	265	209	35757	240
85	33300	249	197	26862	225
75	30400	245	-	21670	225

Therefore will be analyzed the exhaust gas outlet temperature from the economizer at 75%, 85%, and 100% MCR.

4.1.2.1. Analysis at 75% MCR

Analysis at 75% MCR will be performed by using heat balance formula. The following figure will show the diagram between the exhaust gas and the thermal oil fluid.

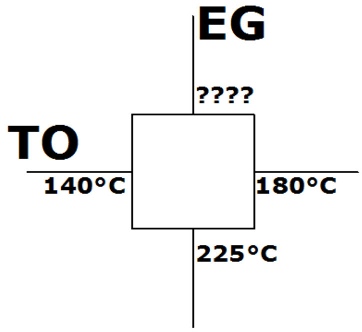


Figure 4..1. Heat Diagram to Find Out the Output Temperature of Exhaust Gas at 75% MCR

To define the outlet temperature of exhaust gas from economizer, the Heat of Thermal Oil (Q_{TO}) will be kept constant. The value of Thermal Oil Heat (Q_{TO}) is as follows.

$$
\begin{aligned}
Q_{TO} &= \dot{m}_{TO} \text{ x } Cp_{TO} \text{ x } \Delta T_{TO} \\
&= 6{,}1067\ {}^{kg}/_{s} \text{ x } 1{,}978\ {}^{kJ}/_{kgK} \text{ x } (180 - 140)K \\
&= 483{,}16 \quad \text{kW}
\end{aligned}
$$

After getting the value of Thermal Oil Heat (Q_{TO}), find the outlet temperature of exhaust gas by using Heat Balance Formula (Q_{TO}=Q_{EG}) as following.

$$
\begin{aligned}
Q_{TO} &= Q_{EG} \\
Q_{TO} &= m^{\cdot}_{EG} \text{ x } Cp_{EG} \text{ x } \Delta T_{EG} \\
T_{2(EG)} &= T_{1(EG)} - \frac{Q_{TO}}{m^{\cdot}_{EG} \text{ x } Cp_{EG}} \\
T_{2(EG)} &= 498{,}15 \text{ K} - \frac{483{,}16 \text{ kW}}{6{,}02 \ ^{kg}/_{s} \text{ x } 1{,}030 \ ^{kJ}/_{kgK}} \\
T_{2(EG)} &= 420{,}2 \quad \text{K} \\
&= 147{,}05 \quad {}^{o}\text{C}
\end{aligned}
$$

Based on the calculation above, it can be concluded that at 75% MCR of the diesel engine, the outlet temperature of exhaust gas after flow through the economizer is 147,05 °C.

4.1.2.2. Analysis at 85% MCR

Analysis at 85% MCR will be performed by using the same way with 75% MCR. The following figure will illustrate the diagram between the exhaust gas and the thermal oil fluid.

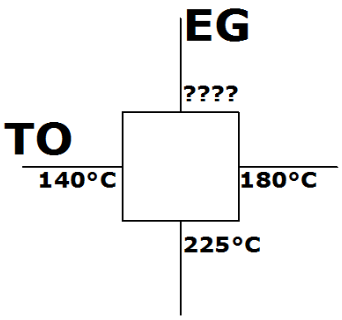


Figure 4.2. Heat Diagram to Find Out the Output Temperature of Exhaust Gas at 85% MCR

The value of Thermal Oil Heat (Q_{TO}) is as follows.

$$
\begin{aligned}
Q_{TO} &= m^{\cdot}_{TO} \text{ x } Cp_{TO} \text{ x } \Delta T_{TO} \\
&= 6{,}1067 \ ^{kg}/_{s} \text{ x } 1{,}978 \ ^{kJ}/_{kgK} \text{ x } (180 - 140)\text{K} \\
&= 483{,}16 \quad \text{kW}
\end{aligned}
$$

After getting the value of Thermal Oil Heat (Q_{TO}), find the outlet temperature of exhaust gas by using Heat Balance Formula (Q_{TO}=Q_{EG}) as following.

$$
\begin{aligned}
Q_{TO} &= Q_{EG} \\
Q_{TO} &= m^{\cdot}_{EG} \text{ x } Cp_{EG} \text{ x } \Delta T_{EG} \\
T_{2(EG)} &= T_{1(EG)} - \frac{Q_{TO}}{m^{\cdot}_{EG} \text{ x } Cp_{EG}}
\end{aligned}
$$

$$T_{2(EG)} = 498{,}15\ K - \frac{483{,}16\ kW}{7{,}462\ ^{kg}/_{s} \ x\ 1{,}030\ ^{kJ}/_{kgK}}$$

$$T_{2(EG)} = 435{,}26 \quad K$$
$$= 162{,}11 \quad ^{o}C$$

Based on the calculation above, it is known that at 85% MCR, the outlet temperature of exhaust gas after flow through the economizer is 162,11 °C.

4.1.2.2. Analysis at 100% MCR

Analysis at 100% MCR will be performed by using the same way with 85% MCR. The following figure will illustrate the diagram between the exhaust gas and the thermal oil fluid.

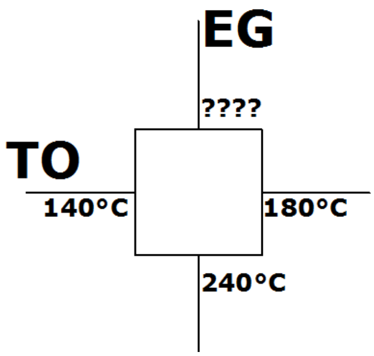


Figure 4.3. Heat Diagram to Find Out the Output Temperature of Exhaust Gas at 100% MCR

The value of Thermal Oil Heat (Q_{TO}) is as follows.

$$Q_{TO} = m^{\cdot}_{TO}\ x\ Cp_{TO}\ x\ \Delta T_{TO}$$
$$= 6{,}1067\ ^{kg}/_{s}\ x\ 1{,}978\ ^{kJ}/_{kgK}\ x\ (180 - 140)K$$
$$= 483{,}16 \quad kW$$

After getting the value of Thermal Oil Heat (Q_{TO}), find the outlet temperature of exhaust gas by using Heat Balance Formula (Q_{TO}=Q_{EG}) as following.

$$Q_{TO} = Q_{EG}$$
$$Q_{TO} = m^{\cdot}_{EG}\ x\ Cp_{EG}\ x\ \Delta T_{EG}$$
$$T_{2(EG)} = T_{1(EG)} - \frac{Q_{TO}}{m^{\cdot}_{EG}\ x\ Cp_{EG}}$$
$$T_{2(EG)} = 513{,}15\ K - \frac{483{,}16\ kW}{9{,}932\ ^{kg}/_{s}\ x\ 1{,}033\ ^{kJ}/_{kgK}}$$
$$T_{2(EG)} = 466{,}05 \quad K$$
$$= 192{,}9 \quad ^{o}C$$

Based on the calculation above, it can be concluded that at 100% MCR, the outlet temperature of exhaust gas after flow through the economizer is 192,9 °C.

4.1.2.4. Summary of Economizer Analysis

Based on the economizer analyses that have been done above, it can be concluded that the heat of exhaust gas can heat up thermal oil fluid in desired value, but with different of exhaust gas outlet temperature in each condition. The following is the graphic of exhaust gas output temperature under some load conditions.

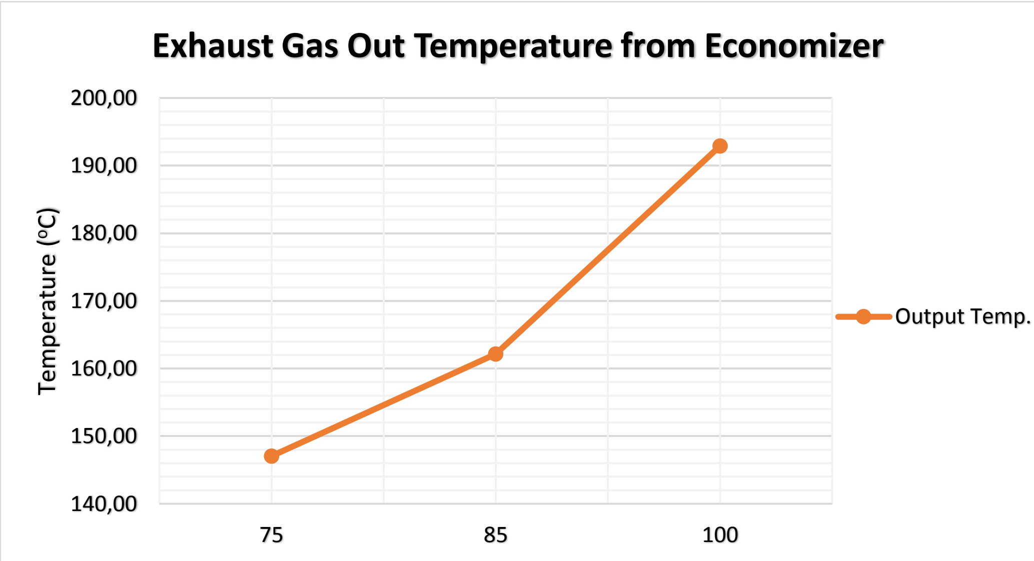


Figure 4.4. Graphic of Exhaust Gas Out Temperature from Economizer in some Load Conditions

From the graphic above, it can be concluded that the outlet temperature of exhaust gas is directly proportional to the engine load. So, when the engine load decreases, the outlet temperature of exhaust gas from economizer will decrease too. It can happen because the exhaust gas temperature of the engine decreases in accordance with the engine load.

4.1.3. Heat Losses Analysis

Heat losses analysis is conducted to define how much heat losses happened along the distribution path of thermal oil, namely from boiler or economizer to the fuel oil tanks and from fuel oil tanks going back to the boiler or economizer.

All types of pipes used along distribution path are JIS G3454 STPG 370S with Schedule of 80, insulated by Glasswool.

4.1.3.1. Thermal Oil Fluid Heat Loss in Boiler Scenario

Boiler scenario is equipped with two pumps with the same capacity of 163,5 m^3/h. The heat losses that happened throughout distribution line is defined in each section of the pipe. The initial scenario of the distribution path for all tanks are the same, that is, starting from distribution line to consumer line. Right after that, the pipe will be branched according to the position of each tank. Return path scenario of thermal oil after pass the fuel tank is the same with the path of thermal oil distribution.

4.1.3.1.1. Storage Tank Portside

The process of thermal oil flow into the fuel oil tank is divided into several pathways, namely distribution line, consumer line, the main line of the fuel tank, and the last is branch line pipe into the fuel tank. After that, the thermal oil will return to the heating equipment. Each of the pathways has different nominal diameter and insulation parameter, so the heat loss calculation shall be carried out in accordance with the path.

a) Distribution Line

After thermal oil was heated up in the boiler to 180°C, the thermal oil will flow along the distribution line pipe with the following parameters.

Table 4.3. Distribution Line Pipe Parameters

Pipe Parameters	
Nominal Size	150A
Schedule	80
Out. Diameter	165,2 mm
Ins. Diameter	154,2 mm
Thickness	11 mm
Length	9,764 m
Thermal Conductivity	33,33 W/mK
Insulation Parameters	
Thickness	30 mm
Thermal Conductivity	0,0554 W/mK

By using parameters above, it can be defined the value of heat loss happened along that line by using equation 2.12., with the mode of heat resistances are oil convection – oil conduction – insulation conduction – air convection. So, the total resistance along this line is calculated by using equation 2.13., as follows.

$$R_{Tot} = R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.}$$
$$= 0{,}5655 \quad \text{Km/W}$$

After getting the value of total resistance, then calculate the value of heat loss happened along the line as follows.

$$Q_{Loss} = 2{,}33 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 179{,}97 \quad ^{o}\text{C}$$

Based on the calculation above, it is known that along the distribution line thermal oil fluid experience temperature drops from 180°C to 179,97°C.

b) Consumer Line

After passing the distribution line, thermal oil fluid will flow to the consumer line with the following parameters.

Table 4.4. Consumer Line Pipe Parameters

Pipe Parameters	
Nominal Size	65A
Schedule	80
Out. Diameter	76,3 mm
Ins. Diameter	69,3 mm
Thickness	7 mm
Length	12,389 m
Thermal Conductivity	33,33 W/mK
Insulation Parameters	
Thickness	25 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$R_{Tot} = R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.}$$

$$= 0{,}995 \qquad \text{Km/W}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 1{,}679 \qquad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 179{,}95 \qquad ^{o}\text{C}$$

Based on the calculation above, it is known that along the consumer line, thermal oil fluid experience temperature drops from 179,97°C to 179,95°C.

c) Main Line of Storage Tank Portside

From consumer line, thermal oil fluid will flow through the main line with the following parameters.

Table 4.5. Main Line Pipe Parameters

Pipe Parameters	
Nominal Size	65A
Schedule	80
Out. Diameter	76,3 mm
Ins. Diameter	69,3 mm
Thickness	7 mm
Length	18,43 m
Thermal Conductivity	33,33 W/mK
Insulation Parameters	
Thickness	25 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, total resistance is calculated as follows.

$$R_{Tot} = R_{\text{Oil Conv.}} + R_{\text{Oil Cond.}} + R_{\text{Ins.Cond.}} + R_{\text{Air Conv.}}$$
$$= 0{,}995 \qquad \text{Km/W}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 2{,}497 \qquad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 179{,}92 \quad {}^{o}C$$

Based on the calculation above, it is known that along the main line, thermal oil fluid experience temperature drops from 179,95°C to 179,92°C.

d) Branch Line of Storage Tank Portside

Right after the main line, thermal oil fluid will flow through the branch line into the entrance of storage tank portside with the following parameters.

Table 4.6. Branch Line Pipe Parameters

Pipe Parameters	
Nominal Size	40A
Schedule	80
Out. Diameter	48,6 mm
Ins. Diameter	43,5 mm
Thickness	5,1 mm
Length	3,901 m
Thermal Conductivity	33,33 W/mK
Insulation Parameters	
Thickness	25 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$\begin{aligned} R_{Tot} &= R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.} \\ &= 1{,}468 \quad \text{Km/W} \end{aligned}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 0{,}358 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 179{,}92 \quad {}^{o}C$$

Based on the calculation above, it is known that along the branch line, thermal oil fluid does not experience temperature drop. Therefore, the temperature of thermal oil in entrance valve of the storage tank portside is 179,92°C.

e) Heat Exchange Inside Storage Tank Portside

Inside the storage tank portside, there is an exchange heat process between fuel oil with thermal oil. This calculation is conducted to find out the outlet temperature of thermal oil fluid from the storage tank portside. Heat balance formula will be used to solve this calculation as follow.

$$
\begin{aligned}
Q_{TO} &= Q_{FO} \\
Q_{TO} &= \dot{m}_{FO} \times Cp_{FO} \times \Delta T_{FO} \\
T_{2(TO)} &= T_{1(TO)} - \frac{Q_{FO}}{\dot{m}_{TO} \times Cp_{TO}} \\
T_{2(TO)} &= 453{,}15\ \text{K} - \frac{3460{,}607\ \text{kW}}{40{,}837\ {}^{kg}/_{s} \times 2{,}122\ {}^{kJ}/_{kgK}} \\
T_{2(TO)} &= 413{,}21 \quad \text{K} \\
&= 140{,}06 \quad {}^{o}\text{C}
\end{aligned}
$$

Based on the calculation above, it is known that the outlet temperature of thermal oil from storage tank portside is 140,06°C.

f) Return Branch Line

From heating coil inside the tank, thermal oil will flow back through the branch line going to the main line with the following parameters.

Table 4.7. Return Branch Line Pipe Parameters

Pipe Parameters	
Nominal Size	40A
Schedule	80
Out. Diameter	48,6 mm
Ins. Diameter	43,5 mm
Thickness	5,1 mm
Length	4,089 m
Thermal Conductivity	34 W/mK
Insulation Parameters	
Thickness	20 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$
\begin{aligned}
R_{Tot} &= R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.} \\
&= 1{,}41 \quad \text{Km/W}
\end{aligned}
$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 0{,}2755 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 140{,}06 \quad ^{\circ}\text{C}$$

Based on the calculation above, it is known that along the return branch line, thermal oil fluid does not experience temperature drops, namely 140,06°C.

g) Return Main Line

From branch line, thermal oil fluid will flow through the main line of storage tank portside with the following parameters.

Table 4.8. Return Main Line Pipe Parameters

Pipe Parameters	
Nominal Size	65A
Schedule	80
Out. Diameter	76,3 mm
Ins. Diameter	69,3 mm
Thickness	7 mm
Length	19,699 m
Thermal Conductivity	34 W/mK
Insulation Parameters	
Thickness	20 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$\begin{aligned} R_{Tot} &= R_{\text{Oil Conv.}} + R_{\text{Oil Cond.}} + R_{\text{Ins.Cond.}} + R_{\text{Air Conv.}} \\ &= 0{,}947 \quad \text{Km/W} \end{aligned}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 1{,}977 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 140{,}03 \quad ^{\circ}\text{C}$$

Based on the calculation above, it is known that along the return main line, thermal oil fluid experience temperature drops from 140,06°C to 140,03°C.

h) Return Consumer Line

After passing the return main line, thermal oil fluid will flow to the return consumer line with the following parameters.

Table 4.9. Return Consumer Line Pipe Parameters

Pipe Parameters	
Nominal Size	65A
Schedule	80
Out. Diameter	76,3 mm
Ins. Diameter	69,3 mm
Thickness	7 mm
Length	14,359 m
Thermal Conductivity	34 W/mK
Insulation Parameters	
Thickness	20 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$R_{Tot} = R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.}$$
$$= 0{,}947 \quad \text{Km/W}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 1{,}44 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 140{,}02 \quad {}^{o}\text{C}$$

Based on the calculation above, it is known that along the consumer line, thermal oil fluid experience temperature drops from 140,03°C to 140,02°C.

i) Deaerated Line

From the return consumer line, thermal oil will flow along the deaerated line pipe with the following parameters.

Table 4.10. Deaerated Line Pipe Parameters

Pipe Parameters	
Nominal Size	150A
Schedule	80
Out. Diameter	165,2 mm
Ins. Diameter	154,2 mm
Thickness	11 mm
Length	8,031 m
Thermal Conductivity	34 W/mK
Insulation Parameters	
Thickness	20 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$R_{Tot} = R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.}$$
$$= 0{,}462 \quad \text{Km/W}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 1{,}651 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 140{,}00 \quad {}^{o}\text{C}$$

Based on the calculation above, it is known that along the deaerated line, thermal oil fluid experience temperature drops from 140,02°C to 140,00°C.

j) Pump Line

From the deaerated line, thermal oil will flow along the pump line pipe with the following parameters.

Table 4.11. Pump Line Parameters

Pipe Parameters	
Nominal Size	200A
Schedule	80
Out. Diameter	216,3 mm
Ins. Diameter	203,6 mm
Thickness	12,7 mm
Length	14,96 m

Thermal Conductivity	34 W/mK
Insulation Parameters	
Thickness	25 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$R_{Tot} = R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.}$$
$$= 0{,}425 \qquad \text{Km/W}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 3{,}342 \qquad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 139{,}96 \qquad ^{\circ}C$$

Based on the calculation above, it is known that along the pump line, thermal oil fluid experience temperature drops from 140,00°C to 139,96°C.

k) Boiler Line

From the pump line, thermal oil will flow along the boiler line with the following parameters.

Table 4.12. Boiler Line Parameters

Pipe Parameters	
Nominal Size	150A
Schedule	80
Out. Diameter	165,2 mm
Ins. Diameter	154,2 mm
Thickness	11 mm
Length	23,581 m
Thermal Conductivity	34 W/mK
Insulation Parameters	
Thickness	20 mm
Thermal Conductivity	0,0554 W/mK

With the same mode of heat resistances, the total resistance can be calculated as follows.

$$R_{Tot} = R_{Oil\ Conv.} + R_{Oil\ Cond.} + R_{Ins.Cond.} + R_{Air\ Conv.}$$
$$= 0{,}462 \quad \text{Km/W}$$

Heat loss value happened along the line is as follows.

$$Q_{Loss} = 4{,}845 \quad \text{kW}$$

Then, define the value of temperature drop as follows.

$$T_{Drop} = 139{,}90 \quad ^{o}C$$

Based on the calculation above, it is known that along the boiler line, thermal oil fluid experience temperature drop from 139,96°C to 139,90°C.

4.1.3.1.2. Storage Tank Starboard

The process of heat losses calculation for fuel oil storage tank starboard is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for storage tank starboard.

Table 4.13. Heat Losses Summary on Storage Tank Starboard in Boiler Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line	0,5655	2,33	180	179,97
Consumer Line	0,995	1,679	179,97	179,95
Main Line	0,995	3,101	179,95	179,92
Branch Line	1,467	0,229	179,92	179,92
Heating Coil	-	-	179,92	140,06
Return Branch Line	1,41	0,18	140,06	140,06
Return Main Line	0,947	2,631	140,06	140,03
Return Consumer Line	0,947	1,44	140,03	140,02
Deaerated Line	0,462	1,651	140,02	140
Pump Line	0,425	3,342	140	139,96
Boiler Line	0,462	4,845	139,96	139,90

As you can see, the result of heat losses calculation for storage tank starboard is about the same as storage tank portside, namely thermal oil temperature in entrance valve of the tank is 179,92°C and thermal oil temperature re-entered to the boiler is 139,90°C.

4.1.3.1.3. Settling Tank

The process of heat losses calculation for fuel oil settling tank is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for settling tank.

Table 4.14. Heat Losses Summary on Settling Tank in Boiler Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line	0,5655	2,33	180	179,97
Consumer Line	0,995	1,679	179,97	179,95
Main Line	0,995	1,642	179,95	179,93
Branch Line	2,071	0,74	179,93	179,93
Heating Coil	-	-	179,93	140,06
Return Branch Line	2,292	0,491	140,06	140,05
Return Main Line	0,947	2,040	140,05	140,03
Return Consumer Line	0,947	1,44	140,03	140,02
Deaerated Line	0,462	1,651	140,02	140
Pump Line	0,425	3,342	140	139,96
Boiler Line	0,462	4,845	139,96	139,90

As you can see, the result of heat losses calculation for settling tank is about the same as storage tank portside, namely thermal oil temperature in entrance valve of the tank is 179,93°C and thermal oil temperature re-entered to the boiler is 139,90°C.

4.1.3.1.4. Service Tank Portside

The process of heat losses calculation for fuel oil service tank portside is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for service tank portside.

Table 4.15. Heat Losses Summary on Service Tank Portside in Boiler Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line	0,5655	2,33	180	179,97
Consumer Line	0,995	1,679	179,97	179,95

Main Line	0,995	1,683	179,95	179,93
Branch Line	2,071	0,796	179,93	179,93
Heating Coil	-	-	179,93	140,06
Return Branch Line	2,292	0,535	140,06	140,05
Return Main Line	0,947	2,073	140,05	140,03
Return Consumer Line	0,947	1,44	140,03	140,02
Deaerated Line	0,462	1,651	140,02	140
Pump Line	0,425	3,342	140	139,96
Boiler Line	0,462	4,845	139,96	139,90

Result of heat losses calculation for service tank portside is about the same as storage tank portside, namely thermal oil temperature in entrance valve of the tank is 179,93°C and thermal oil temperature re-entered to the boiler is 139,90°C.

4.1.3.1.5. Service Tank Starboard

The process of heat losses calculation for fuel oil service tank starboard is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for service tank starboard

Table 4.16. Heat Losses Summary on Service Tank Starboard in Boiler Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line	0,5655	2,33	180	179,97
Consumer Line	0,995	1,679	179,97	179,95
Main Line	0,995	2,676	179,95	179,92
Branch Line	2,071	0,732	179,92	179,91
Heating Coil	-	-	179,91	140,06
Return Branch Line	2,292	0,433	140,06	140,05
Return Main Line	0,947	2,091	140,05	140,03
Return Consumer Line	0,947	1,44	140,03	140,02
Deaerated Line	0,462	1,651	140,02	140
Pump Line	0,425	3,342	140	139,96
Boiler Line	0,462	4,845	139,96	139,90

The result of heat losses calculation for service tank starboard is about the same as storage tank portside, namely thermal oil temperature in entrance valve of the tank is 179,92°C and thermal oil temperature re-entered to the boiler is 139,90°C.

4.1.3.2. Thermal Oil Fluid Heat Loss in Economizer Scenario

Economizer scenario is equipped with two pumps with the same capacity of 23,7 m^3/h. The heat losses that happened along distribution line is defined in each section of the pipe as the same with the boiler scenario.

4.1.3.2.1. Storage Tank Portside

The process of heat losses calculation for fuel oil storage tank portside in economizer scenario is the same with the storage tank portside in boiler scenario. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for storage tank portside.

Table 4.17. Summary of Heat Losses for Storage Tank Portside in Economizer Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line (65A)	0,995	1,979	180	179,84
Distribution Line (125A)	0,659	0,066	179,84	179,84
Distribution Line (150A)	0,565	1,144	179,84	179,75
Consumer Line	0,995	1,676	179,75	179,61
Main Line	0,995	2,491	179,61	179,41
Branch Line	1,467	0,357	179,41	179,39
Heating Coil	-	-	179,39	140,71
Return Branch Line	1,41	0,277	140,71	140,69
Return Main Line	0,947	1,989	140,69	140,52
Return Consumer Line	0,947	1,448	140,52	140,40
Deaerated Line	0,462	1,658	140,40	140,27
Pump Line	0,822	2,308	140,27	140,07
Economizer Line	0,947	1,398	140,07	139,96

From the table above, it can be known that thermal oil temperature in entrance valve of the tank is 179,39°C and thermal oil temperature re-entered to the economizer is 139,96°C.

4.1.3.2.2. Storage Tank Starboard

The process of heat losses calculation for fuel oil storage tank starboard is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for storage tank starboard.

Table 4.18. Summary of Heat Losses for Storage Tank Starboard in Economizer Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line (65A)	0,995	1,979	180	179,84
Distribution Line (125A)	0,659	0,066	179,84	179,84
Distribution Line (150A)	0,565	1,144	179,84	179,75
Consumer Line	0,995	1,676	179,75	179,61
Main Line	0,995	3,093	179,61	179,37
Branch Line	1,467	0,229	179,37	179,35
Heating Coil	-	-	179,35	140,74
Return Branch Line	1,41	0,181	140,74	140,72
Return Main Line	0,947	2,645	140,72	140,51
Return Consumer Line	0,947	1,448	140,51	140,40
Deaerated Line	0,462	1,658	140,40	140,27
Pump Line	0,822	2,308	140,27	140,07
Economizer Line	0,947	1,398	140,07	139,96

From the table above, it can be known that thermal oil temperature in entrance valve of the tank is 179,35°C and thermal oil temperature re-entered to the economizer is 139,96°C.

4.1.3.2.3. Settling Tank

The process of heat losses calculation for fuel oil settling tank is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section.

Table 4.19. Summary of Heat Losses for Settling Tank in Economizer Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line (65A)	0,995	1,979	180	179,84
Distribution Line (125A)	0,659	0,066	179,84	179,84
Distribution Line (150A)	0,565	1,144	179,84	179,75
Consumer Line	0,995	1,676	179,75	179,61
Main Line	0,995	1,638	179,61	179,48
Branch Line	2,071	0,737	179,48	179,42
Heating Coil	-	-	179,42	140,68
Return Branch Line	2,292	0,494	140,68	140,64
Return Main Line	0,947	2,052	140,64	140,47
Return Consumer Line	0,947	1,448	140,47	140,40
Deaerated Line	0,462	1,658	140,40	140,27
Pump Line	0,822	2,308	140,27	140,07
Economizer Line	0,947	1,398	140,07	139,96

From the table above, it can be known that thermal oil temperature in entrance valve of the tank is 179,42°C and thermal oil temperature re-entered to the economizer is 139,96°C.

4.1.3.2.4. Service Tank Portside

The process of heat losses calculation for fuel oil service tank portside is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for service tank portside.

Table 4.20. Summary of Heat Losses for Service Tank Portside in Economizer Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line (65A)	0,995	1,979	180	179,84
Distribution Line (125A)	0,659	0,066	179,84	179,84
Distribution Line (150A)	0,565	1,144	179,84	179,75
Consumer Line	0,995	1,676	179,75	179,61
Main Line	0,995	1,679	179,61	179,48
Branch Line	2,071	0,793	179,48	179,42
Heating Coil	-	-	179,42	140,68
Return Branch Line	2,292	0,539	140,68	140,64
Return Main Line	0,947	2,086	140,64	140,46
Return Consumer Line	0,947	1,448	140,46	140,40
Deaerated Line	0,462	1,658	140,40	140,27
Pump Line	0,822	2,308	140,27	140,07
Economizer Line	0,947	1,398	140,07	139,96

From the table above, it can be known that thermal oil temperature in entrance valve of the tank is 179,42°C and thermal oil temperature re-entered to the economizer is 139,96°C.

4.1.3.2.5. Service Tank Starboard

The process of heat losses calculation for fuel oil service tank starboard is the same with the storage tank portside. The full calculations are attached in this document. The following is the summary of heat losses in each section of thermal oil distribution for service tank starboard.

Table 4.21. Summary of Heat Losses for Service Tank Starboard in Economizer Scenario

Section	Total Resistance (Km/W)	Heat Loss (kW)	Initiate Temp. (°C)	Temp. Drop (°C)
Distribution Line (65A)	0,995	1,979	180	179,84
Distribution Line (125A)	0,659	0,066	179,84	179,84
Distribution Line (150A)	0,565	1,144	179,84	179,75
Consumer Line	0,995	1,676	179,75	179,61
Main Line	0,995	2,669	179,61	179,40
Branch Line	2,071	0,729	179,40	179,34
Heating Coil	-	-	179,34	140,76
Return Branch Line	2,292	0,436	140,76	140,72
Return Main Line	0,947	2,105	140,72	140,55
Return Consumer Line	0,947	1,448	140,55	140,40
Deaerated Line	0,462	1,658	140,40	140,27
Pump Line	0,822	2,308	140,27	140,07
Economizer Line	0,947	1,398	140,07	139,96

It is known that thermal oil temperature in entrance valve of the tank is 179,34°C and thermal oil temperature re-entered to the economizer is 139,96°C.

4.1.4. Time Needed to Heat Fuel Oil

It is intended to determine how long time needed to heat fuel in each fuel tanks by using boiler and economizer.

4.1.4.1. Boiler Scenario

In boiler scenario, the thermal oil fluid is distributed by using two pumps with the same capacity of 163,5 m^3/h. It can be done by using the same formula as economizer analysis, namely heat balance equation. The full calculation is attached in this document, the following table will show the summary of time needed to heat fuel oil in each tank by using boiler pump.

Table 4.22. Heating Duration Summary of Boiler Scenario

Fuel Oil Tanks	Time Needed to Heat Fuel Oil in Hours
Storage Tank Portside	0,673
Storage Tank Starboard	0,701
Settling Tank	0,053
Service Tank Portside	0,105
Service Tank Starboard	0,105

From the table above, it is known that the longest and shortest time needed to heat fuel in boiler scenario is storage tank starboard and settling tank, namely 0,701 and 0,053 hours respectively.

4.1.4.2. Economizer Scenario

In economizer scenario, the thermal oil fluid is distributed by using two pumps with the same capacity of 23,7 m^3/h. It can be done by using the same formula as boiler scenario above. The full calculation is attached in this document. the following table will show the summary of time needed to heat fuel oil in each tank by using economizer pump.

Table 4.23. Heating Duration Summary of Economizer Scenario

Fuel Oil Tanks	Time Needed to Heat Fuel Oil in Hours
Storage Tank Portside	4,706
Storage Tank Starboard	4,907
Settling Tank	0,369
Service Tank Portside	0,730
Service Tank Starboard	0,732

From the table above, it is known that the longest and shortest time needed to heat fuel in boiler scenario is storage tank starboard and settling tank, namely 4,907 and 0,369 hours respectively.

4.2. Pipe Stress Analysis

In conducting pipe stress analysis, it must be known all equipment dimension. The dimension can be found in isometric drawing of the system or plant. This document will analyze the heating coil arrangement inside each fuel oil tanks and will be done by using simulation in a software, called Caesar II. All isometric drawing of heating coil pipe in each fuel tanks must be converted into this software. There are two kinds of load in this document, namely sustained and expansion load.

4.2.1. Storage Tank Portside

The fuel oil capacity of storage tank portside is 299,78 m^3 with the 63,12-metre length of the heating coil. Heating coil pipe is using JIS G3459, the material of SUS 316 with Nominal Diameter of 50 and Schedule 40. The temperature of thermal oil fluid flowing therein the heating coil is 180°C and ambient temperature inside the tank is 45°C. The following figure will show the result of pipe stress simulation in sustained load.

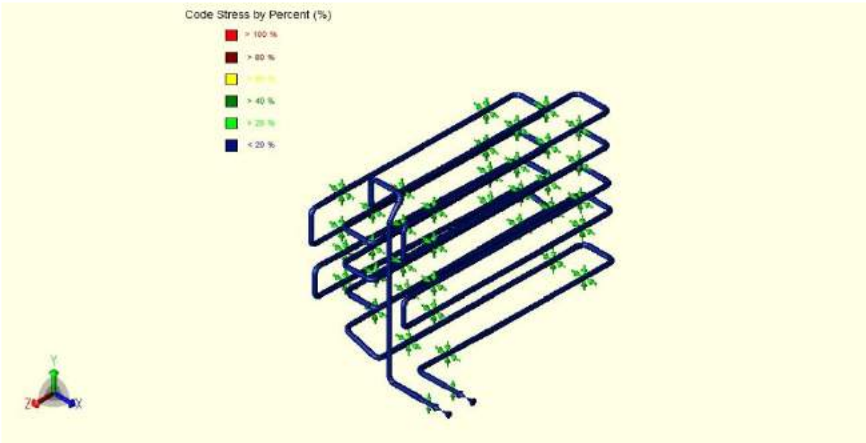


Figure 4.5. Result of Pipe Stress Simulation Storage Tank Portside for Sustained Load in Caesar II

From the figure above, it is known that the result of sustained load simulation for heating coil inside storage tank portside is in blue color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 135190,7 kPa. Maximum code stress in this simulation is 12530,5 kPa, happened at Node 80. That means the maximum stress happened is 9,3% of allowable stress.

The following figure will show the result of pipe stress simulation in expansion load.

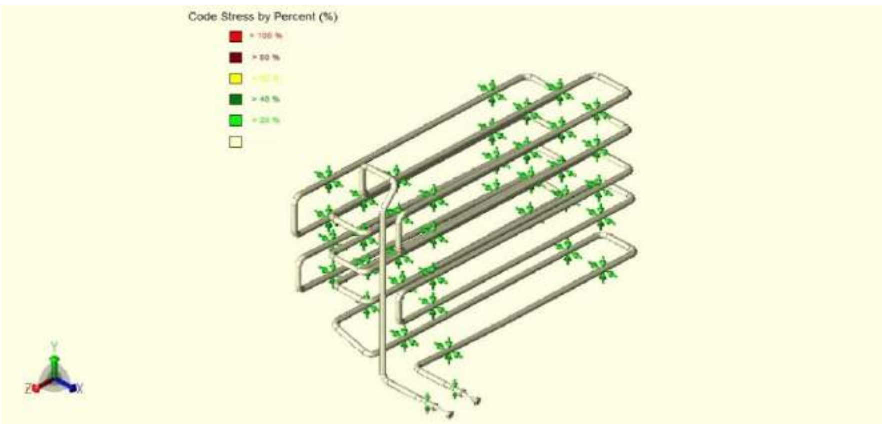


Figure 4.6. Result of Pipe Stress Simulation Storage Tank Portside for Expansion Load in Caesar II

From the figure above, it is known that the result of expansion load simulation for heating coil inside storage tank portside is in white metallic color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 329024,3 kPa. Maximum code stress in this simulation is 25628,9 kPa, happened at Node 79. That means the maximum stress happened is 7,8% of allowable stress.

4.2.2. Storage Tank Starboard

The fuel oil capacity of storage tank starboard is 312,26 m^3 with 63,75 meters length of the heating coil. Heating coil pipe is using JIS G3459, the material of SUS 316 with Nominal Diameter of 50 and Schedule 40. The temperature of thermal oil fluid flowing therein the heating coil is 180°C and ambient temperature inside the tank is 45°C. The following figure will show the result of pipe stress simulation in sustained load.

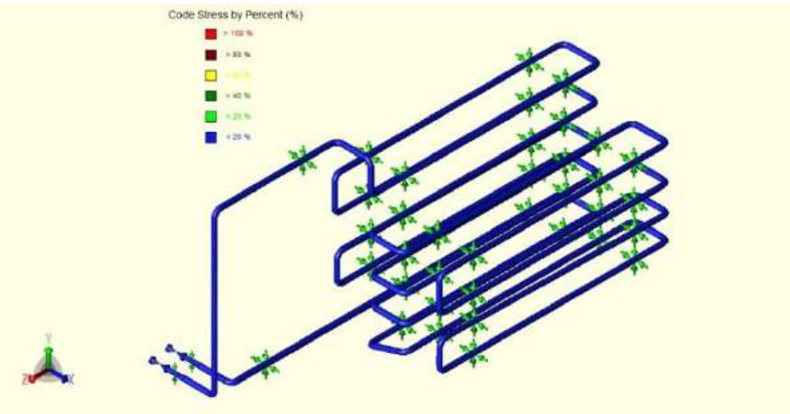


Figure 4.7. Result of Pipe Stress Simulation Storage Tank Starboard for Sustained Load in Caesar II

From the figure above, it is known that the result of sustained load simulation for heating coil inside storage tank starboard is in blue color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 135190,7 kPa. Maximum code stress in this simulation is 14336 kPa, happened at Node 468. That means the maximum stress happened is 10,6% of allowable stress.

The following figure will show the result of pipe stress simulation in expansion load.

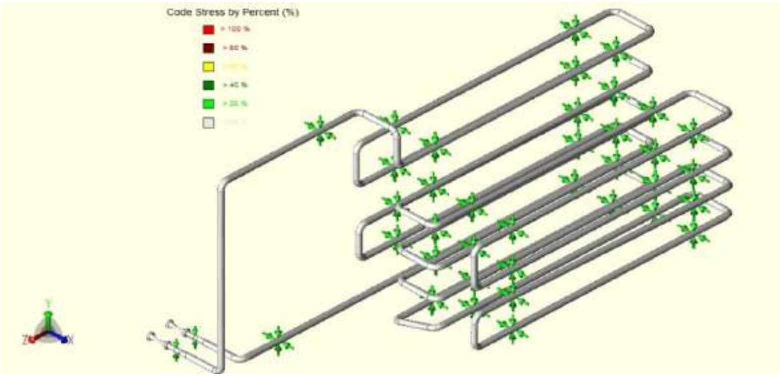


Figure 4.8. Result of Pipe Stress Simulation Storage Tank Starboard for Expansion Load in Caesar II

From the figure above, it is known that the result of expansion load simulation for heating coil inside storage tank starboard is in white metallic color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 335110,8 kPa. Maximum code stress in this simulation is 40062,9 kPa, happened at Node 460. That means the maximum stress happened is 12% of allowable stress.

4.2.3. Settling Tank

The fuel oil capacity of settling tank is 23,74 m^3 with 31,11 meters length of the heating coil. Heating coil pipe is using JIS G3459, the material of SUS 316 with Nominal Diameter of 40 and Schedule 40. The temperature of thermal oil fluid flowing therein the heating coil is 180°C and ambient temperature inside the tank is 60°C. The following figure will show the result of pipe stress simulation in sustained load.

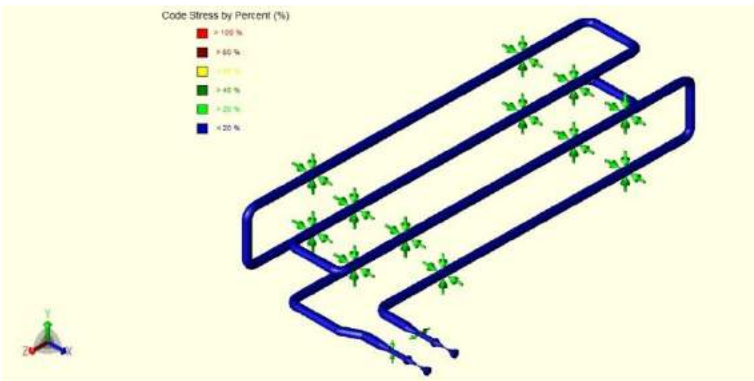


Figure 4.9. Result of Pipe Stress Simulation Settling Tank for Sustained Load in Caesar II

From the figure above, it is known that the result of sustained load simulation for heating coil inside settling tank is in blue color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 135190,7 kPa. Maximum code stress in this simulation is 3953,1 kPa, happened at Node 92. That means the maximum stress happened is 2,9% of allowable stress.

The following figure will show the result of pipe stress simulation in expansion load.

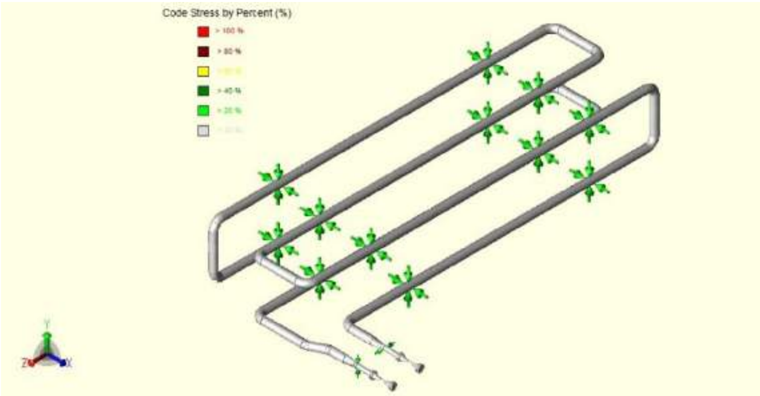


Figure 4.10. Result of Pipe Stress Simulation Settling Tank for Expansion Load in Caesar II

From the figure above, it is known that the result of expansion load simulation for heating coil inside settling tank is in white metallic color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 338905,7 kPa. Maximum code stress in this simulation is 20297,7 kPa, happened at Node 90. That means the maximum stress happened is 6% of allowable stress.

4.2.4. Service Tank Portside

The fuel oil capacity of service tank portside is 23,74 m^3 with 15,56 meters length of the heating coil. Heating coil pipe is using JIS G3459, the material of SUS 316 with Nominal Diameter of 40 and Schedule 40. The temperature of thermal oil fluid flowing therein the heating coil is 180°C and ambient temperature inside the tank is 90°C. The following figure will show the result of pipe stress simulation in sustained load.

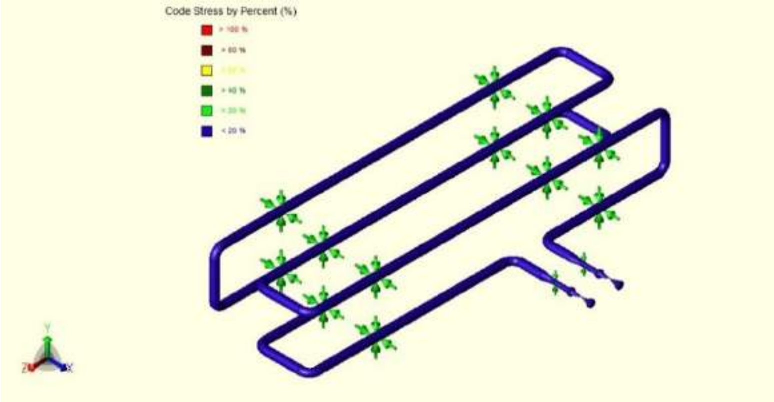


Figure 4.11. Result of Pipe Stress Simulation Service Tank Portside for Sustained Load in Caesar II

From the figure above, it is known that the result of sustained load simulation for heating coil inside service tank portside is in blue color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 135190,7 kPa. Maximum code stress in this simulation is 3079,7 kPa, happened at Node 191. That means the maximum stress happened is 2,3% of allowable stress.

The following figure will show the result of pipe stress simulation in expansion load.

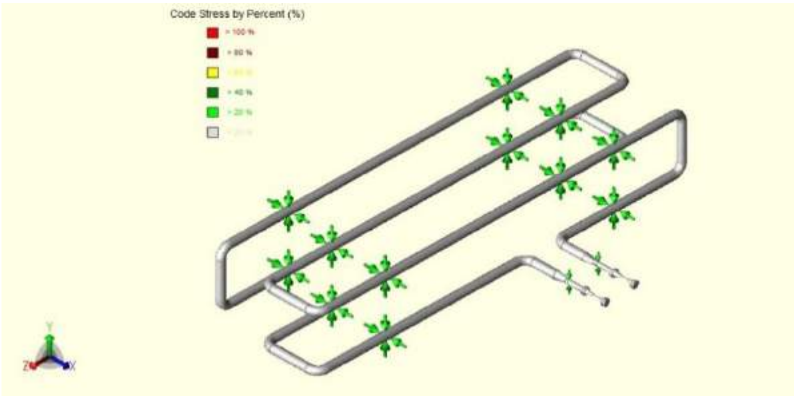


Figure 4.12. Result of Pipe Stress Simulation Service Tank Portside for Expansion Load in Caesar II

From the figure above, it is known that the result of expansion load simulation for heating coil inside service tank portside is in white metallic color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 339846,3 kPa. Maximum code stress in this simulation is 19711,8 kPa, happened at Node 150. That means the maximum stress happened is 5,8% of allowable stress.

4.2.5. Service Tank Starboard

The fuel oil capacity of service tank starboard is 23,74 m^3 with 15,56 meters length of the heating coil. Heating coil pipe is using JIS G3459, the material of SUS 316 with Nominal Diameter of 40 and Schedule 40. The temperature of thermal oil fluid flowing therein the heating coil is 180^{o}C and ambient temperature inside the tank is 90^{o}C. The following figure will show the result of pipe stress simulation in sustained load.

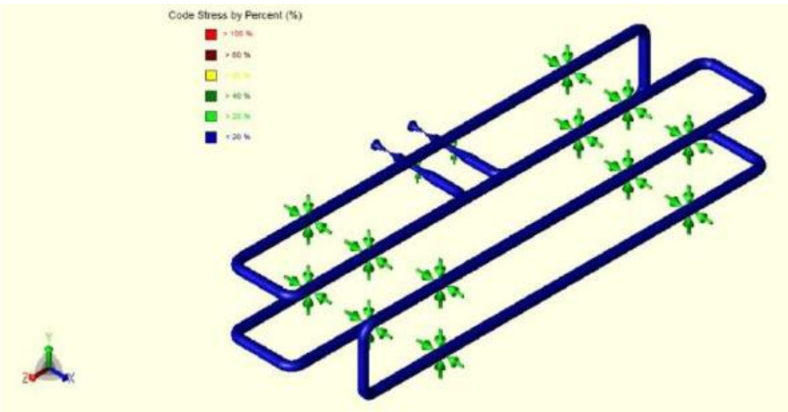


Figure 4.13. Result of Pipe Stress Simulation Service Tank Starboard for Sustained Load in Caesar II

From the figure above, it is known that the result of sustained load simulation for heating coil inside service tank starboard is in blue color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 135190,7 kPa. Maximum code stress in this simulation is 3079,8 kPa, happened at Node 192. That means the maximum stress happened is 2,3% of allowable stress.

The following figure will show the result of pipe stress simulation in expansion load.

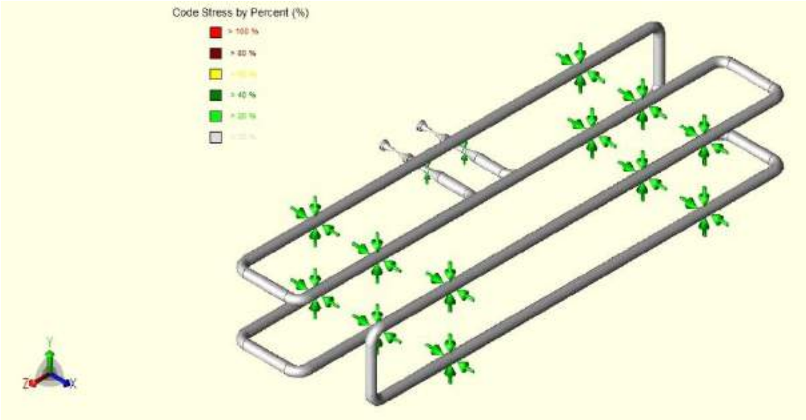


Figure 4.14. Result of Pipe Stress Simulation Service Tank Starboard for Expansion Load in Caesar II

From the figure above, it is known that the result of expansion load simulation for heating coil inside service tank starboard is in white metallic color, which means that the value of sustained load is below 20% of allowable stress. The full result of simulation will be attached in this document. Allowable stress for this simulation based on ASME B31.3 is 339785,9 kPa. Maximum code stress in this simulation is 22648,7 kPa, happened at Node 150. That means the maximum stress happened is 6,7% of allowable stress.

4.3. Sensitivity Analysis

Sensitivity analysis is intended to define the condition where the pipe arrangement will become a failure, or the allowable stress of the pipe is lower than the actual stress happened on the system. This analysis will be done by removing one or more support that used in the pipe arrangement. Then it will be known what effect will happen when the pipe support is removed from a piping system.

4.3.1. Storage Tank Portside

The arrangement of the heating coil inside the storage tank portside can be seen in figure 4.7. From that figure, it is known that the heating coil is in good condition (stress happened is 9,3% of allowable stress). The following figure shows the condition where the heating coil pipe arrangement become a failure.

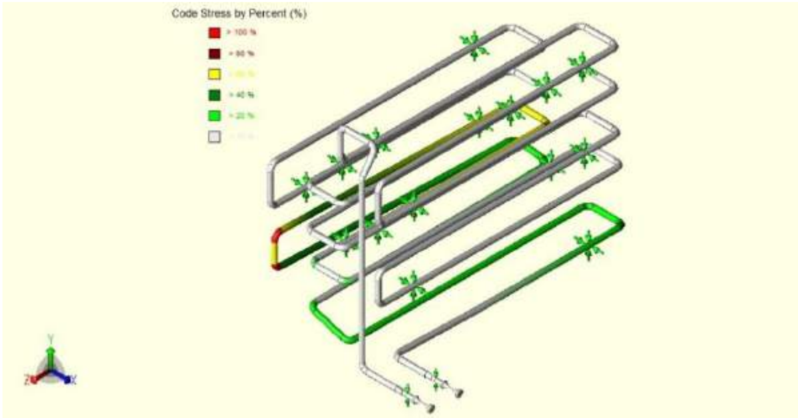


Figure 4.15. Sensitivity Analysis of Storage Tank Portside in Caesar II

The result show this piping system is failed at Node 388, 389, 390, 398, 399, and 400 with code stress values are 145151,8; 150590,4; 151396,5; 145574,0; 141871,8; 136127,2 kPa, respectively. They are can be seen in the figure below as a red area. Meanwhile, the allowable stress value is 135190,7 kPa.

4.3.2. Storage Tank Starboard

The arrangement of the heating coil inside the storage tank starboard can be seen in figure 4.7. From that figure, it is known that the heating coil is in good condition (stress happened is 10,6% of allowable stress). The following figure shows the condition where the heating coil pipe arrangement become a failure.

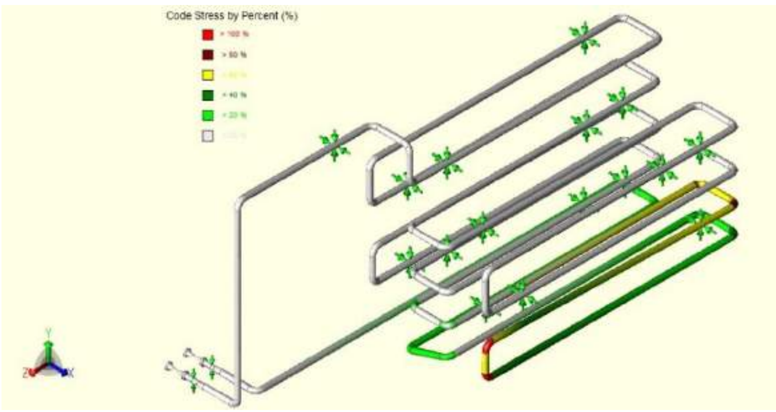


Figure 4.16. Sensitivity Analysis of Storage Tank Starboard in Caesar II

The result show this piping system is failed at Node 148, 149, 150, 158, 159, and 160 with code stress values are 138361,6; 144679,5; 148845,7; 154225,2;

153331,6; 147931,2 kPa, respectively. They are can be seen in the figure below as a red area. Meanwhile, the allowable stress value is 135190,7 kPa.

4.3.3. Settling Tank

The arrangement of the heating coil inside the settling tank can be seen in figure 4.7. From that figure, it is known that the heating coil is in good condition (stress happened is 15% of allowable stress). The following figure shows the condition where the heating coil pipe arrangement become a failure.

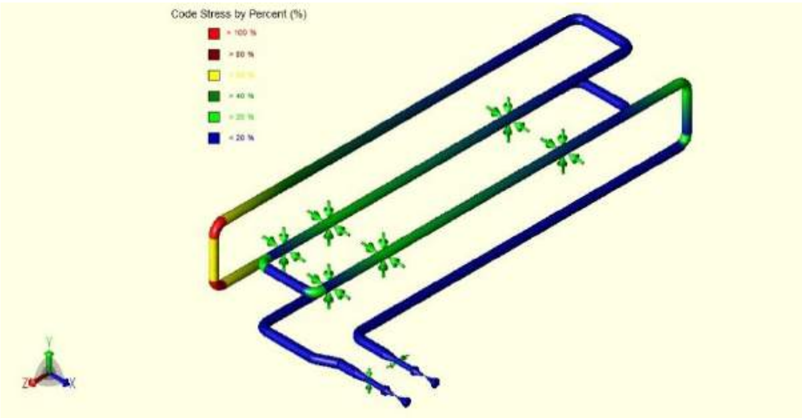


Figure 4.17. Sensitivity Analysis of Settling Tank in Caesar II

The result show this piping system is failed at Node 148, 149, 150, 158, 159, and 160 with code stress values are 140692,2; 143338,8; 144348,5; 144645,3; 143652,4; and 140839,7 kPa, respectively. They are can be seen in the figure below as a red area. Meanwhile, the allowable stress value is 135190,7 kPa.

4.3.4. Service Tank Portside

The arrangement of the heating coil inside the service tank portside can be seen in figure 4.7. From that figure, it is known that the heating coil is in good condition (stress happened is 2,3% of allowable stress). The following figure shows the condition where the heating coil pipe arrangement become a failure.

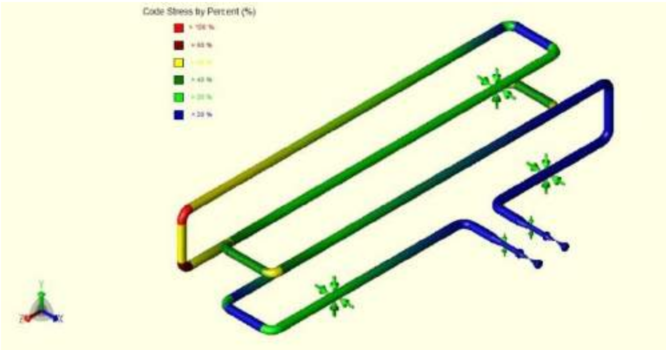


Figure 4.18. Sensitivity Analysis of Service Tank Portside in Caesar II

The result show this piping system is failed at Node 148, 149, and 150 with code stress values are 142334,5; 143016,3; and 142088,3 kPa, respectively. They are can be seen in the figure below as a red area. Meanwhile, the allowable stress value is 135190,7 kPa.

4.3.5. Service Tank Starboard

The arrangement of the heating coil inside the service tank starboard can be seen in figure 4.7. From that figure, it is known that the heating coil is in good condition (stress happened is 4,6% of allowable stress). The following figure shows the condition where the heating coil pipe arrangement become a failure.

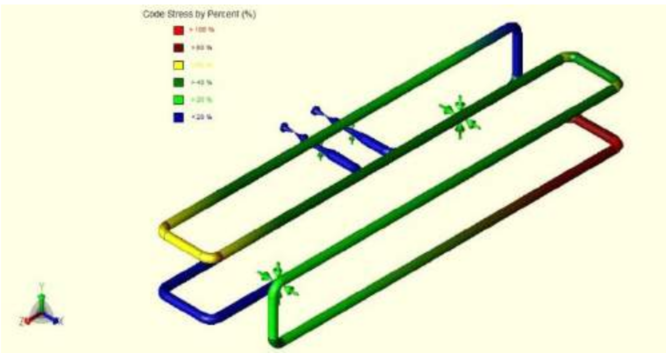


Figure 4.19. Sensitivity Analysis of Service Tank Starboard in Caesar II

The result show this piping system is failed at Node 168, 169, 179, and 180 with code stress values are 174385,7; 153245,0; 152594,4; and 172468,2 kPa, respectively. They are can be seen in the figure below as a red area. Meanwhile, the allowable stress value is 135190,7 kPa.

CHAPTER V
CONCLUSION & SUGGESTION

6.1. Conclusion

Based on the data analysed in the previous chapter, some conclusions can be made as follow.

1. The exhaust gas outlet temperatures from economizer used on MT. Parigi based on shop test result are as follow.
   - 75% MCR of Main Engine, exhaust gas outlet temperature from economizer is 147,05°C;
   - 85% MCR of Main Engine, exhaust gas outlet temperature from economizer is 162,11°C;
   - 100% MCR of Main Engine, exhaust gas outlet temperature from economizer is 192,9°C.

2. Thermal oil heating system on MT. Parigi is able to distribute heat into fuel oil tanks in accordance with the design value in order to increase the fuel oil temperature inside each fuel tanks, both using boiler scenario and economizer scenario, as follow.

Table 6.1. Summary of Temperatures Input, Output, and Re-entered Heating Equipments

Fuel Oil Tanks	Temperatures (°C)					
	Boiler Scenario			Economizer Scenario		
	Input	Output	Re-entered	Input	Output	Re-entered
Storage Tank P/S	179,92	140,06	139,90	179,39	140,71	139,96
Storage Tank S/B	179,92	140,06	139,90	179,35	140,74	139,96
Settling Tank	179,93	140,06	139,90	179,42	140,68	139,96
Service Tank P/S	179,93	140,06	139,90	179,42	140,68	139,96
Service Tank S/B	179,91	140,06	139,90	179,34	140,76	139,96

From the table above, it is known that the re-entered temperature of the thermal oil to the heating equipment in boiler scenario is lower than economizer scenario. It has happened because the pump capacity in boiler scenario is bigger than the pump capacity in economizer. Bigger the capacity of the pump, the value of temperature decrease also become bigger.

3. Heating duration of fuel oil in each fuel tanks will be shown in the following table.

Table 6.2. Summary of Heating Duration on MT. Parigi

Fuel Oil Tanks	Heating Duration (hours)	
	Boiler Scenario	Economizer Scenario
Storage Tank P/S	0,673	4,706
Storage Tank S/B	0,701	4,907
Settling Tank	0,053	0,369
Service Tank P/S	0,105	0,730
Service Tank S/B	0,105	0,732

Based on the summary of heating duration in the table above, it can be known that boiler scenario has faster heating duration than economizer scenario in full pump capacity. It can be happen because the pump capacity of boiler scenario is bigger than the pump capacity of economizer scenario. The bigger pump capacity, the faster the duration of heating will take place.

4. The heating coil system inside fuel tanks that have been installed onboard is safe to use, or able to withstand the pressure and temperature of the thermal oil flowing therein. It means that the allowable pipe stress of heating coil is bigger than the stress that happened in the system. Here are the details.
    - Storage Tank Portside, maximum stress happened is 12530,5 kPa at Node 80, meanwhile, the allowable stress value is 135190,7 kPa;
    - Storage Tank Starboard, maximum stress happened is 14336 kPa at Node 468, meanwhile, the allowable stress value is 135190,7 kPa;
    - Settling Tank, maximum stress happened is 3953,1 kPa at Node 92, meanwhile, the allowable stress value is 135190,7 kPa;
    - Service Tank Portside, maximum stress happened is 3079,7 kPa at Node 91, meanwhile, the allowable stress value is 135190,7 kPa;
    - Service Tank Starboard, maximum stress happened is 3079,8 kPa at Node 92, meanwhile, the allowable stress value is 135190,7 kPa.

6.2. Suggestion

Based on the conclusion above, the author has several suggestions for the operation of the system and for the writing of this bachelor thesis, as follows.

1. The heating duration in the conclusion above is operated in the maximum capacity of the pump. If the heating duration is too fast, the ship's crew can slow it down by regulating the capacity of the pump, for example by arranging the opening of the valve that has been installed on board.

2. Further analysis on heating coil pipe stress due to sustained load and expansion load can be conducted by using another pipe stress software, in order to compare the result of a software to another software, for example, Autopipe.

3. Engineering evaluation in analyzing the pipe stress distribution line on MT. Parigi is needed. It is intended to improve is the distribution line of thermal oil piping system on this ship is safe to use or not.

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AUTHOR BIODATA

The author was born on 25th December 1995 in Tanjungpinang, as the second child of three siblings. His father's name is Ingot Pieter Agustin Panggabean and his mother's name is Rinipan, SE. The author has completed the formal education in TK St. Bernadeth Tanjungpinang, SD Katolik Tanjungpinang, SMP Katolik Tanjungpinang, and SMAN 2 Tanjungpinang. The author continued his study for bachelor degree in Double Degree Programme of Marine Engineering (DDME) of Institut Teknologi Sepuluh Nopember (ITS) and Hochschule Wismar, with student registration number is 4213101038. In the college, the author took an area of expertise in Marine Machinery and System (MMS) Laboratory. During the college, the author was active in academic and non-academic activities, namely staff of accommodation and transportation in YES Summit 2014, senior staff of accomodation and transportation in YES Summit 2015, staff of publication and documentation in Festival of Art and Talents ITS (FANTASI) 2015, following some courses such as Project Management Course and AutoCAD Basic Training Course, and becoming an lecture assistant in Marine Machinery and System (MMS) Laboratory. The author got a scholarship throughout his studies in the university in 2017, namely Yayasan Toyota & Astra 2016. The author has done the first on the job training in PT. Anggrek Hitam Shipyard, Batam, and the second on the job Training in PT. Pertamina Refinery Unit (RU) V and Marketing Operation Region (MOR) VI Balikpapan.

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ATTACHMENT A
ALFA LAVAL ECONOMIZER DATA

Technical data for Aalborg EXV economiser

1 General data

- Project No.:..202770
- Hull No.:...AH-037, AH-038

2 Technical specification

- Type:...EXV632 46 48.3 900DD
- Quantity:...1 Pc(s).

3 Through the pipes, thermal fluid

- Quantity:...23,7 m³/h
- Inlet temperature:...140 ºC
- Outlet temperature:..180 ºC
- Flow resistance:...17,5 m.l.c.

4 Dimensions

- Diameter without insulation:..1,664 mm
- Height excl. cones:...3,700 mm
- Height incl. cones:..5,100 mm
- Exhaust gas connection:..DN 800
- Weight (empty):...6,200 kg
- Liquid contents:...1,190 litres

5 Design data

- Main engine:...MAN 6S35MC7.1-TII

Note: Please check exhaust gas data with motor maker

Exhaust gas side:
Engine load 85 (%)

- Capacity:...500 kW
- Exhaust gas quantity:...33.300 kg/h
- Exhaust gas temperature before heater..248 °C
- Exhaust gas temperature after heater...197 °C
- Pressure drop exhaust gasses...1.232 Pa.

Engine load 100 (%)

- Capacity:...619 kW
- Exhaust gas quantity:..37.200kg/h
- Exhaust gas temperature before heater..265 °C
- Exhaust gas temperature after heater...209 °C
- Pressure drop exhaust gasses...1.545 Pa.

6 Soot cleaning equipment

- Required quantity of water:..24 l/min
- Required pressure of water at the nozzle:...2 bar(g)

7 Firefighting equipment

- Required quantity of water:..22,5 l/min
- Required pressure of water at the nozzle:..3 bar(g)

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ATTACHMENT B
THERMAL OIL FLUID PROPERTIES

Properties of Therminol® 66 vs Temperatures

Temperature °C	Density kg/m³	Thermal Conductivity W/m.K	Heat Capacity kJ/kg.K	Viscosity Dynamic mPa.s	Viscosity Kinematic mm²/s**	Vapour pressure (absolute) kPa*
0	1021.5	0.118	1.495	1324.87	1297.01	-
10	1014.9	0.118	1.529	344.26	339.20	-
20	1008.4	0.118	1.562	123.47	122.45	-
30	1001.8	0.117	1.596	55.60	55.51	-
40	995.2	0.117	1.630	29.50	29.64	-
50	988.6	0.116	1.665	17.64	17.84	-
60	981.9	0.116	1.699	11.53	11.74	-
70	975.2	0.115	1.733	8.06	8.26	0.01
80	968.5	0.115	1.768	5.93	6.12	0.02
90	961.8	0.114	1.803	4.55	4.73	0.03
100	955.0	0.114	1.837	3.60	3.77	0.05
110	948.2	0.113	1.873	2.92	3.08	0.08
120	941.4	0.112	1.908	2.42	2.58	0.12
130	934.5	0.111	1.943	2.05	2.19	0.18
140	927.6	0.111	1.978	1.75	1.89	0.27
150	920.6	0.110	2.014	1.52	1.65	0.40
160	913.6	0.109	2.050	1.34	1.46	0.58
170	906.6	0.108	2.086	1.18	1.30	0.83
180	899.5	0.107	2.122	1.06	1.17	1.17
190	892.3	0.107	2.158	0.95	1.06	1.62
200	885.1	0.106	2.195	0.86	0.97	2.23
210	877.8	0.105	2.231	0.78	0.89	3.02
220	870.4	0.104	2.268	0.72	0.82	4.06
230	863.0	0.103	2.305	0.66	0.77	5.39
240	855.5	0.102	2.342	0.61	0.71	7.10
250	847.9	0.100	2.379	0.57	0.67	9.25
260	840.3	0.099	2.417	0.53	0.63	11.95
270	832.5	0.098	2.455	0.49	0.59	15.31
280	824.6	0.097	2.492	0.46	0.56	19.46
290	816.6	0.096	2.531	0.44	0.54	24.55
300	808.5	0.095	2.569	0.41	0.51	30.73
310	800.3	0.093	2.608	0.39	0.49	38.22
320	792.0	0.092	2.647	0.37	0.47	47.20
330	783.5	0.091	2.686	0.35	0.45	57.94
340	774.8	0.089	2.726	0.34	0.43	70.68
350	765.9	0.088	2.766	0.32	0.42	85.74
360	756.9	0.086	2.806	0.31	0.41	103.42
370	747.7	0.085	2.847	0.30	0.39	124.09
380	738.2	0.084	2.889	0.28	0.38	148.13

* 1 bar = 100 kPa - ** 1 mm²/s = 1 cSt

Note: Values quoted are typical values obtained in the laboratory from production samples. Other samples might exhibit slightly different data. Specifications are subject to change. Write to Solutia for current sales specifications.

Physical Property Formulae

Density (kg/m³) = $-0.614254 * T(°C) - 0.000321 * T^2(°C) + 1020.62$

Heat capacity (kJ/kg.K) = $0.003313 * T(°C) + 0.0000008970785 * T^2(°C) + 1.496005$

Thermal Conductivity (W/m.K) = $-0.000033 * T(°C) - 0.00000015 * T^2(°C) + 0.118294$

Kinematic Viscosity (mm²/s) = $e^{\left(\frac{586.375}{T(°C)+62.5} - 2.2809\right)}$

Vapour Pressure (kPa) = $e^{\left(\frac{-9094.51}{T(°C)+340} + 17.6371\right)}$

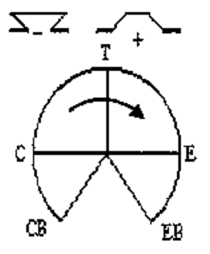
ATTACHMENT C
SHOP TRIAL RECORD OF DIESEL ENGINE

4. Summary Data of Shop Trial

Engine No.	SB6S35-13178	Owner	PERTAMINA	Output	4440 kW
Project No.	E14B040	Shipyard	PT.ANGGREK HITAM	Test Date	2014-10-27

	Unit	1	2	3	4	5	6	7
Load	%	25	50	75	85	100	110	
Engine speed	rpm	109.0	137.3	157.2	163.9	173.0	178.6	
Engine output	BHP	1510	3019	4529	5133	6038	6642	
Engine output	kW	1110	2220	3330	3774	4440	4884	
Room temperature	℃	17.0	18.0	18.0	21.0	20.4	22.0	
Room humidity	%	59	58	58	56	55	52	
Barometer pressure	mmbar	1018	1018	1018	1018	1018	1018	
Fuel oil temperature	℃	24	24	24	24	24	24	
Fuel oil consumption	kg/h	227.4	434.6	618.3	800.0	827.6	907.6	
Fuel oil consumption	g/kW/h	204.84	195.77	185.68	184.86	186.39	185.82	
Fuel oil consumption (ISO.)	g/kW/h	203.80	194.50	184.59	183.67	185.10	184.58	
Max.Combustion pressure	bar	69.2	100.3	127.8	135.5	145.7	150.3	
Compression pressure	bar	42.7	69.8	100.0	110.0	124.8	131.0	
Mean effective pressure	bar	7.56	12.01	15.73	17.10	19.06	20.31	
Fuel injection pump index	mm	23.0	33.0	44.0	47.0	53.0	57.0	
Exh.temp cylinder outlet	℃	299.2	328.3	350.8	364.2	395.0	428.3	
Exh.temp T/C inlet	℃	290.0	385.0	365.0	380.0	420.0	455.0	
Exh.temp T/C outlet	℃	240.0	240.0	225.0	225.0	240.0	265.0	
Turbocharger speed	rpm	10538	16370	19689	20799	21288	23079	
Scav.air temperature	℃	32	30	32	34	34	35	
Scav.air pressure	bar	0.62	1.50	2.49	2.80	3.18	3.30	
Turbocharger gas inlet press	bar	0.50	1.31	2.19	2.50	2.90	3.08	

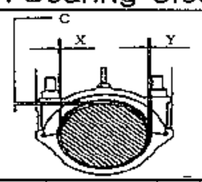
Crank Shaft Deflection



CRANK PIN POSITION VIEW FROM FLY WHEEL

Cold Condition								Room Temp. 21 ℃
Cylinder No.		1	2	3	4	5	6	
No.1 &	CB	0	0	0	0	0	0	
Aft most	C	7.0	2.0	-2.0	-2.0	-5.0	-4.0	
± 15.0	T	16.0	11.0	2.0	-2.0	-11.0	-8.0	
Other	E	13.0	9.0	1.0	-2.0	-6.0	-4.0	
± 15.0	EB	4.0	6.0	0.0	3.0	0.0	0.0	
Hot Condition								43 ℃
	CB	0	0	0	0	0	0	
	C	13.0	0.0	-4.0	-4.0	1.0	-4.0	
	T	9.0	3.0	-3.0	-8.0	3.0	-5.0	
	E	16.0	4.0	-3.0	-5.0	8.0	-4.0	
	EB	9.0	4.0	-1.0	0.0	0.0	-1.0	

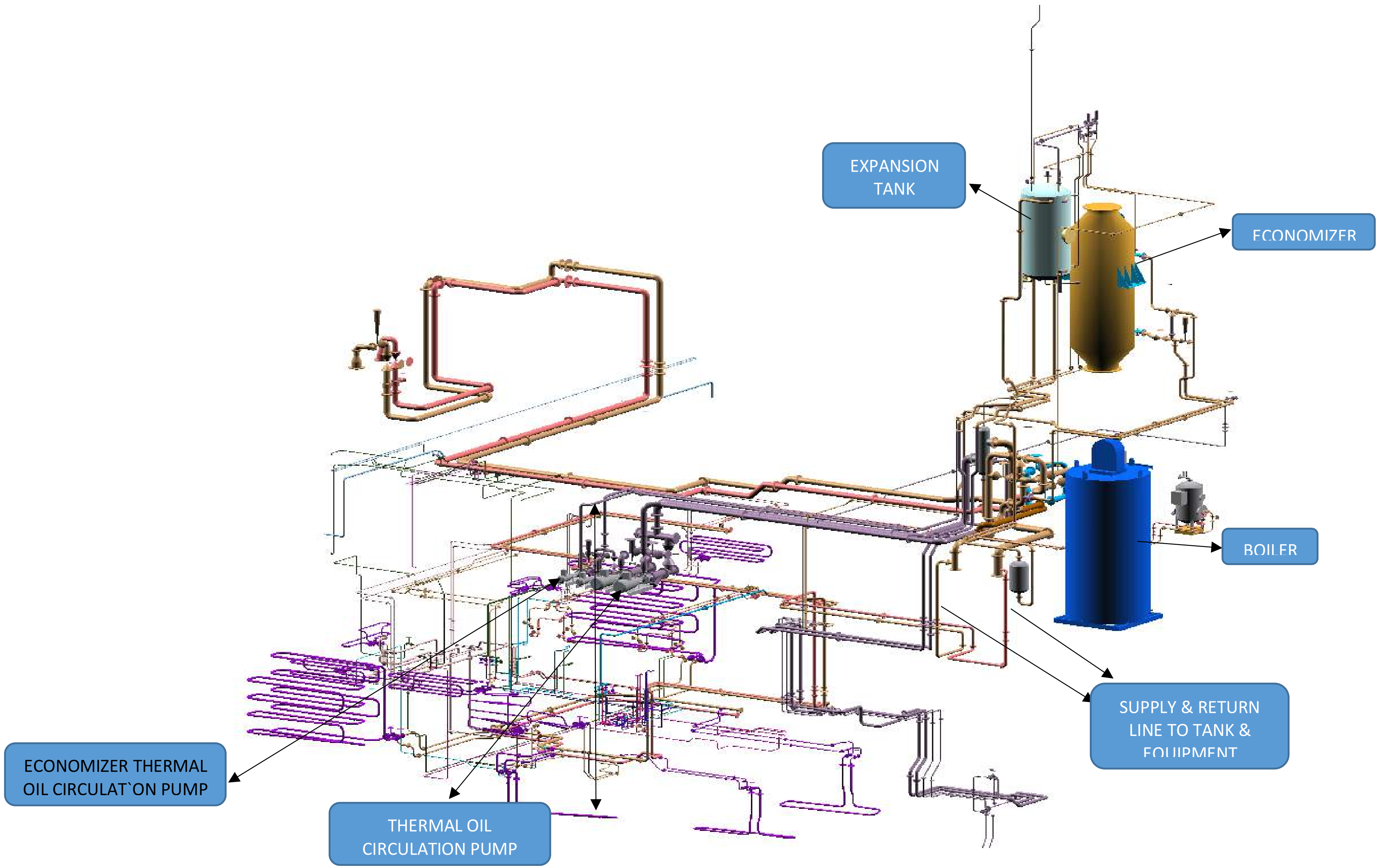
Main Bearing Clearance



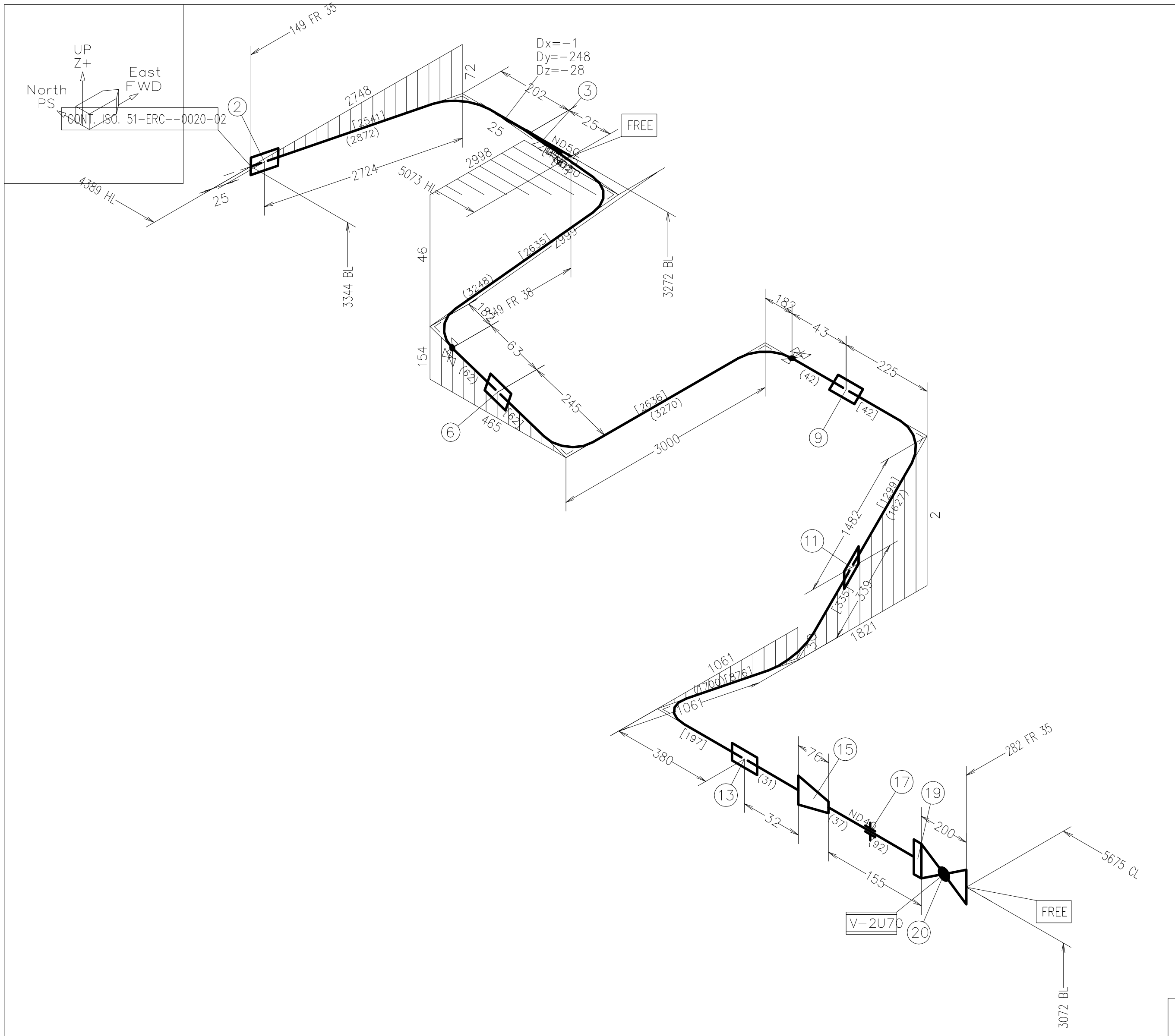
Standard (After Stay Bolt Tightened)	Vertical (C)		Unit
	Min	Max	
	25	41	1/100 mm

Cyl' No	1	2	3	4	5	6	7	8	9	10
FC	28	28	29	28	29	28	28	28		
AC	28	28	29	28	29	28	28	28		

ATTACHMENT D
THERMAL OIL DISTRIBUTION PATH


EXPANSION TANK
ECONOMIZER
BOILER
SUPPLY & RETURN LINE TO TANK & EQUIPMENT
ECONOMIZER THERMAL OIL CIRCULAT`ON PUMP
THERMAL OIL CIRCULATION PUMP

ATTACHMENT E
ISOMETRIC DRAWING OF HEATING COIL INSIDE STORAGE TANK PORTSIDE



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50		1.4	PIPE:NA -SUS 316	SUS 316		2872
2	50			SLEEVE	SUS 316	10K	
3	50			SLEEVE	SUS 316	10K	
4	50		1.4	PIPE:NA -SUS 316	SUS 316		3248
5	50		1.4	PIPE:NA -SUS 316	SUS 316		62
6	50			SLEEVE	SUS 316	10K	
7	50		1.4	PIPE:NA -SUS 316	SUS 316		3270
8	50		1.4	PIPE:NA -SUS 316	SUS 316		42
9	50			SLEEVE	SUS 316	10K	
10	50		1.4	PIPE:NA -SUS 316	SUS 316		1627
11	50			SLEEVE	SUS 316	10K	
12	50		1.4	PIPE:NA -SUS 316	SUS 316		1700
13	50			SLEEVE	SUS 316	10K	
14	50			PIPE:S80 -STPG 370	STPG 370		31
15	50	40			STPG 370		
16	40			PIPE:S80 -STPG 370	STPG 370		37
17	40			DOUBLER 10K	SS400	10K	
18	40			PIPE:S80 -STPG 370	STPG 370		92
19	40			FLANGE	ROLLED STEEL	PN16	
20	40			GLOBAL CONTROL VALVE WITH BE	CAST IRON	PN16	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		12820
50			PIPE:S80 -STPG 370	STPG 370		31
40			PIPE:S80 -STPG 370	STPG 370		129
40			GLOBAL CONTROL VALVE WITH BE	CAST IRON	PN16	1
40			FLANGE	ROLLED STEEL	PN16	1
50			SLEEVE	SUS 316	10K	6
40			DOUBLER 10K	SS400	10K	1
50	40			STPG 370		1

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-~~A5~~51038-002001

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa – Batam Indonesia
Tel : (62-778)472720, Fax :(62-778)472730

LINE NO. 002

PIPING ISOMETRIC
51038-002001
THERMAL OIL SYSTEM

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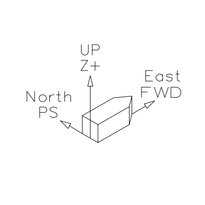

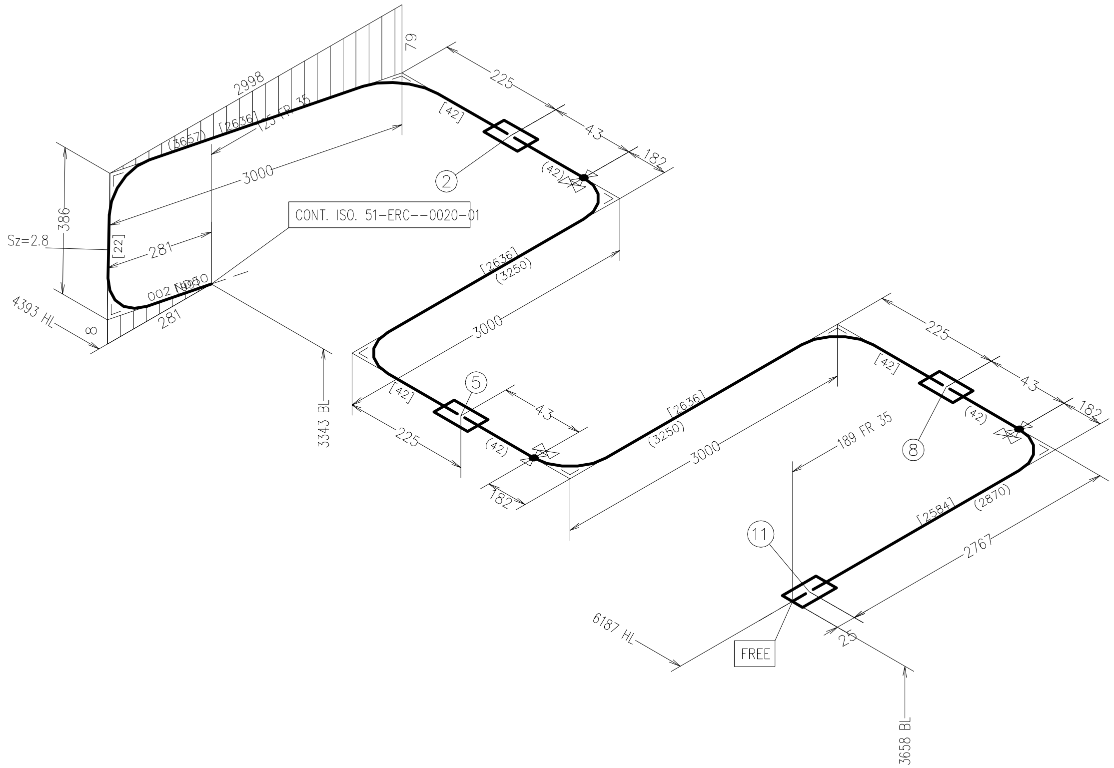

MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
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2	50			SLEEVE	SUS 316	10K	
3	50		1.4	PIPE:NA -SUS 316	SUS 316		42
4	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
5	50			SLEEVE	SUS 316	10K	
6	50		1.4	PIPE:NA -SUS 316	SUS 316		42
7	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
8	50			SLEEVE	SUS 316	10K	
9	50		1.4	PIPE:NA -SUS 316	SUS 316		42
10	50		1.4	PIPE:NA -SUS 316	SUS 316		2870
11	50			SLEEVE	SUS 316	10K	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		13152
50			SLEEVE	SUS 316	10K	4

SPOOL LIST

SPOOL NUMBER	WEIGHT
– –	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-A51038-002002

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LINE NO. 002

PIPING ISOMETRIC
51038-002002
THERMAL OIL SYSTEM

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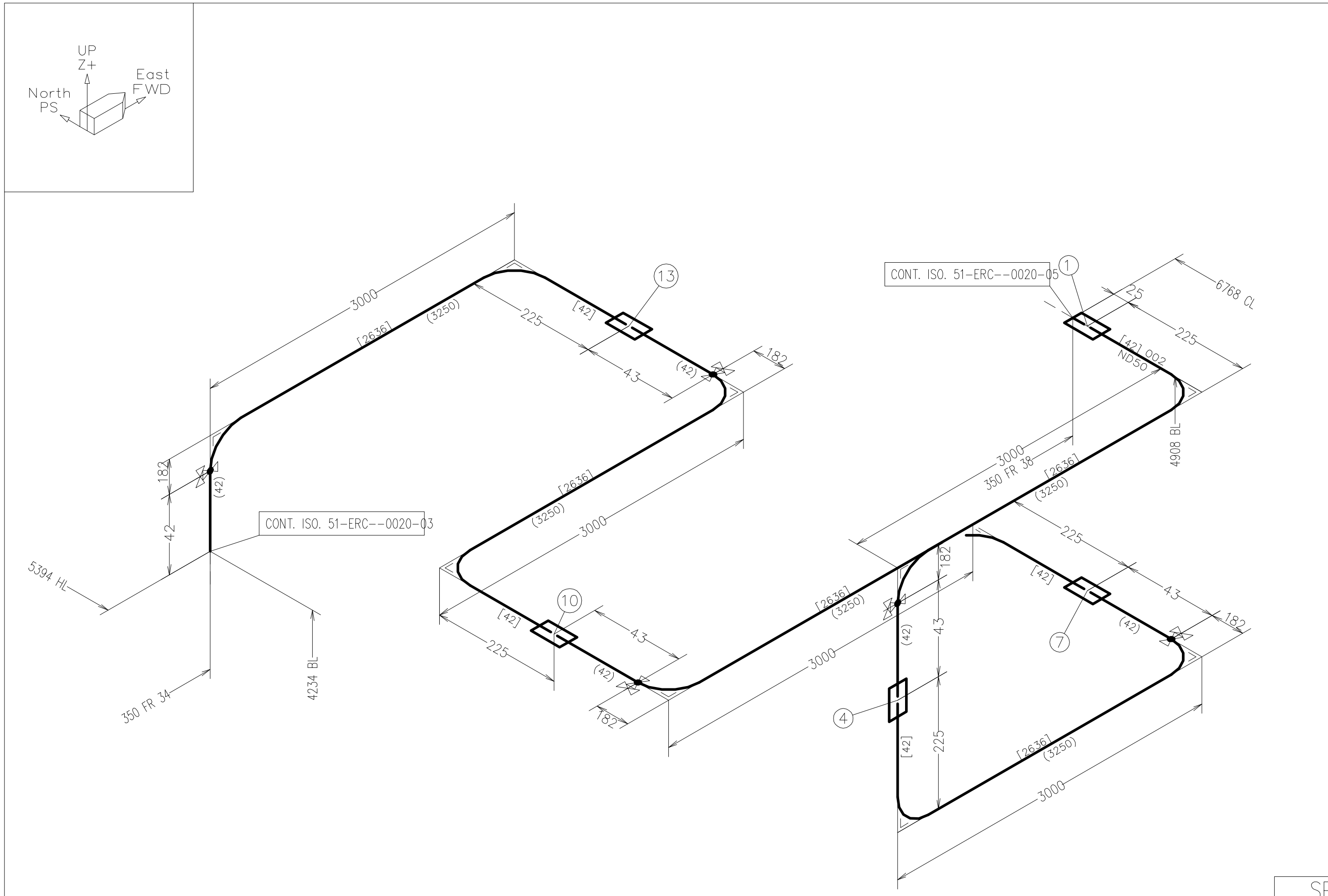

MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50			SLEEVE	SUS 316	10K	
2	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
3	50		1.4	PIPE:NA -SUS 316	SUS 316		42
4	50			SLEEVE	SUS 316	10K	
5	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
6	50		1.4	PIPE:NA -SUS 316	SUS 316		42
7	50			SLEEVE	SUS 316	10K	
8	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
9	50		1.4	PIPE:NA -SUS 316	SUS 316		42
10	50			SLEEVE	SUS 316	10K	
11	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
12	50		1.4	PIPE:NA -SUS 316	SUS 316		42
13	50			SLEEVE	SUS 316	10K	
14	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
15	50		1.4	PIPE:NA -SUS 316	SUS 316		42

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		16459
50			SLEEVE	SUS 316	10K	5

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-A51038-002004

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa - Batam Indonesia
Tel : (62-778)472720, Fax :(62-778)472730

LINE NO. 002

PIPING ISOMETRIC
51038-002004
THERMAL OIL SYSTEM

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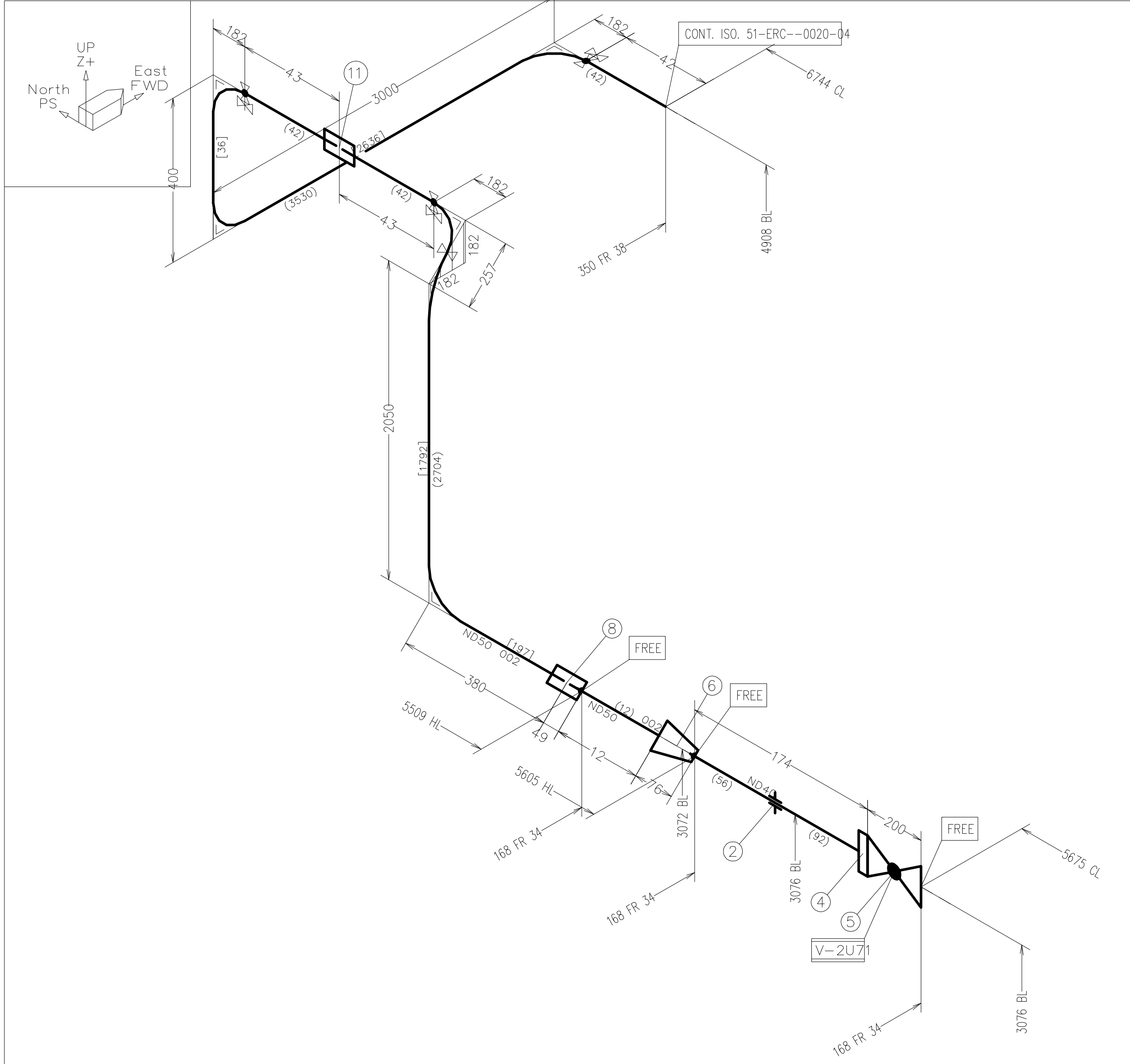


MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	40		1.2	PIPE:NA -SUS 316	SUS 316		56
2	40			DOUBLER 10K	SS400	10K	
3	40		1.2	PIPE:NA -SUS 316	SUS 316		92
4	40			FLANGE	ROLLED STEEL	PN16	
5	40			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
6	50	40			STPG 370		
7	50		1.4	PIPE:NA -SUS 316	SUS 316		12
8	50			SLEEVE	SUS 316	10K	
9	50		1.4	PIPE:NA -SUS 316	SUS 316		2704
10	50		1.4	PIPE:NA -SUS 316	SUS 316		42
11	50			SLEEVE	SUS 316	10K	
12	50		1.4	PIPE:NA -SUS 316	SUS 316		42
13	50		1.4	PIPE:NA -SUS 316	SUS 316		3530
14	50		1.4	PIPE:NA -SUS 316	SUS 316		42

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
40		1.2	PIPE:NA -SUS 316	SUS 316		148
50		1.4	PIPE:NA -SUS 316	SUS 316		6371
40			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	1
40			FLANGE	ROLLED STEEL	PN16	1
40			DOUBLER 10K	SS400	10K	1
50			SLEEVE	SUS 316	10K	2
50	40			STPG 370		1

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

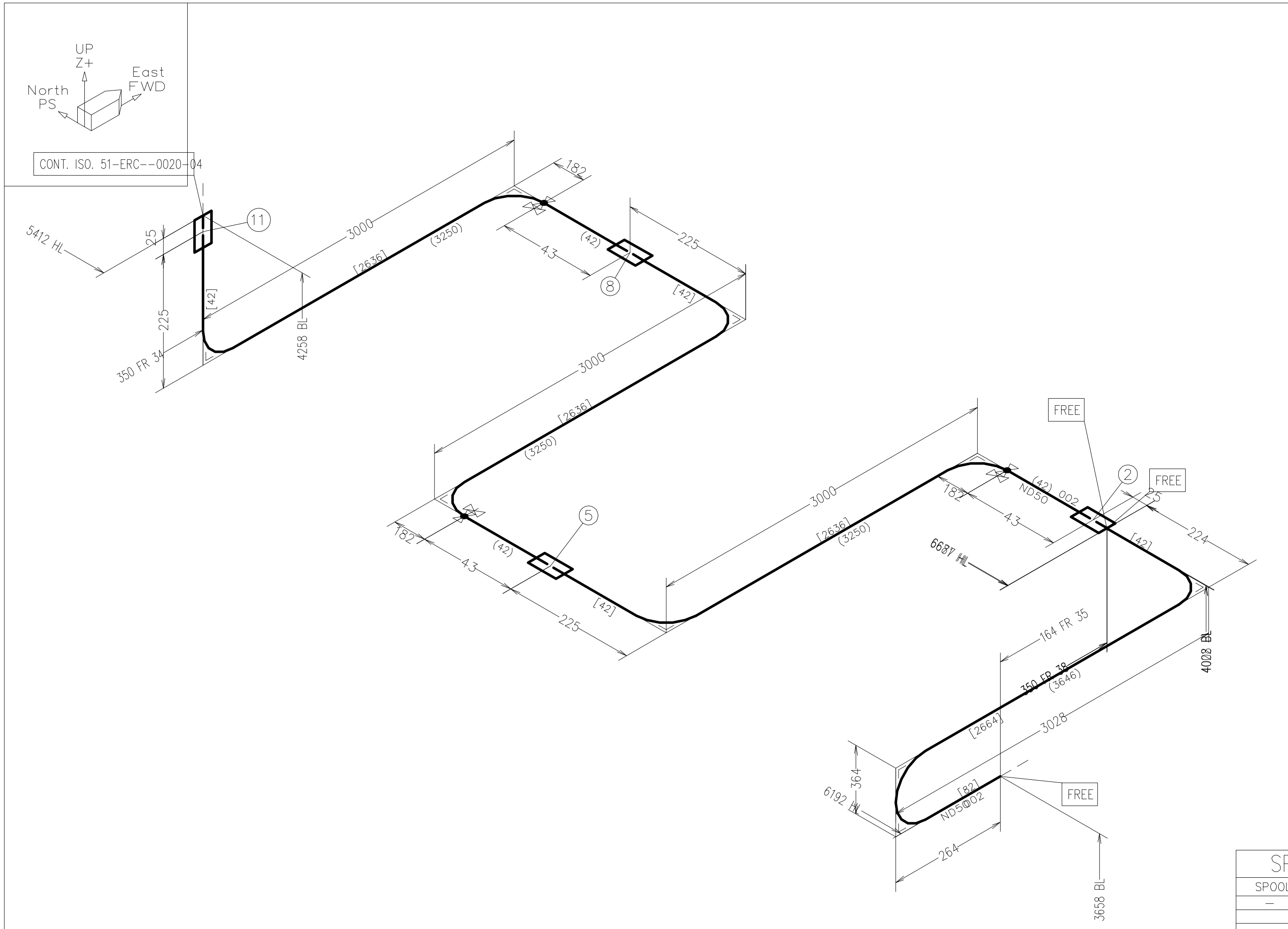
ISO NO. ERC-A51038-002005

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa – Batam Indonesia
Tel : (62-778)472720, Fax :(62-778)472730

LINE NO. 002

PIPING ISOMETRIC
51038-002005
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	51038	050		08	0	



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50		1.4	PIPE:NA -SUS 316	SUS 316		3646
2	50			SLEEVE	SUS 316	10K	
3	50		1.4	PIPE:NA -SUS 316	SUS 316		42
4	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
5	50			SLEEVE	SUS 316	10K	
6	50		1.4	PIPE:NA -SUS 316	SUS 316		42
7	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
8	50			SLEEVE	SUS 316	10K	
9	50		1.4	PIPE:NA -SUS 316	SUS 316		42
10	50		1.4	PIPE:NA -SUS 316	SUS 316		3250
11	50			SLEEVE	SUS 316	10K	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		13522
50			SLEEVE	SUS 316	10K	4

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-A51038-002003

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
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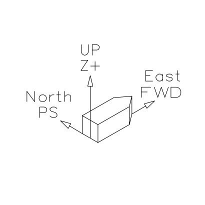
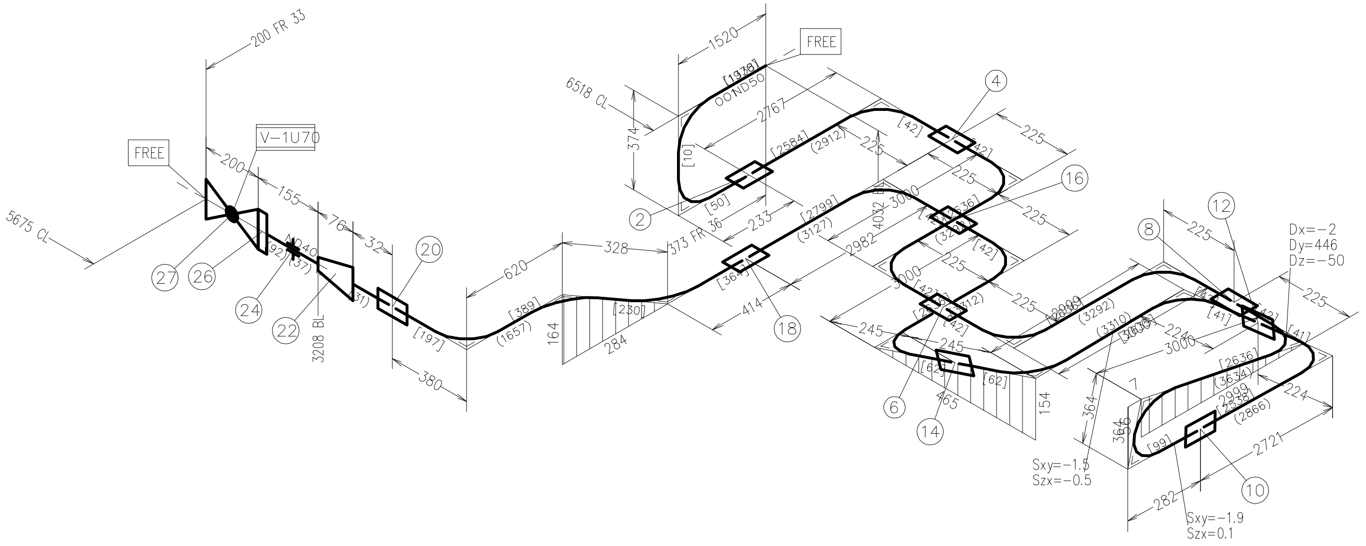
LINE NO. 002

PIPING ISOMETRIC
51038-002003
THERMAL OIL SYSTEM

ISO	A3	51038	050		09	0	
SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS

ATTACHMENT F
ISOMETRIC DRAWING OF HEATING COIL INSIDE STORAGE TANK STARBOARD





MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50		1.4	PIPE:NA -SUS 316	SUS 316		1970
2	50			SLEEVE	SUS 316	10K	
3	50		1.4	PIPE:NA -SUS 316	SUS 316		2912
4	50			SLEEVE	SUS 316	10K	
5	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
6	50			SLEEVE	SUS 316	10K	
7	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
8	50			SLEEVE	SUS 316	10K	
9	50		1.4	PIPE:NA -SUS 316	SUS 316		3634
10	50			SLEEVE	SUS 316	10K	
11	50		1.4	PIPE:NA -SUS 316	SUS 316		2866
12	50			SLEEVE	SUS 316	10K	
13	50		1.4	PIPE:NA -SUS 316	SUS 316		3310
14	50			SLEEVE	SUS 316	10K	
15	50		1.4	PIPE:NA -SUS 316	SUS 316		3312
16	50			SLEEVE	SUS 316	10K	
17	50		1.4	PIPE:NA -SUS 316	SUS 316		3127
18	50			SLEEVE	SUS 316	10K	
19	50		1.4	PIPE:NA -SUS 316	SUS 316		1657
20	50			SLEEVE	SUS 316	10K	
21	50			PIPE:S80 -STPG 370	STPG 370		31
22	50	40			STPG 370		
23	40			PIPE:S80 -STPG 370	STPG 370		37
24	40			DOUBLER 10K	SS400	10K	
25	40			PIPE:S80 -STPG 370	STPG 370		92
26	40			FLANGE	ROLLED STEEL	PN16	
27	40			GLOBAL CONTROL VALVE WITH BE	CAST IRON	PN16	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		29371
50			PIPE:S80 -STPG 370	STPG 370		31
40			PIPE:S80 -STPG 370	STPG 370		129
40			GLOBAL CONTROL VALVE WITH BE	CAST IRON	PN16	1
40			FLANGE	ROLLED STEEL	PN16	1
50			SLEEVE	SUS 316	10K	10
40			DOUBLER 10K	SS400	10K	1
50	40			STPG 370		1

SPOOL LIST

SPOOL NUMBER	WEIGHT
– –	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-A51038-001001

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
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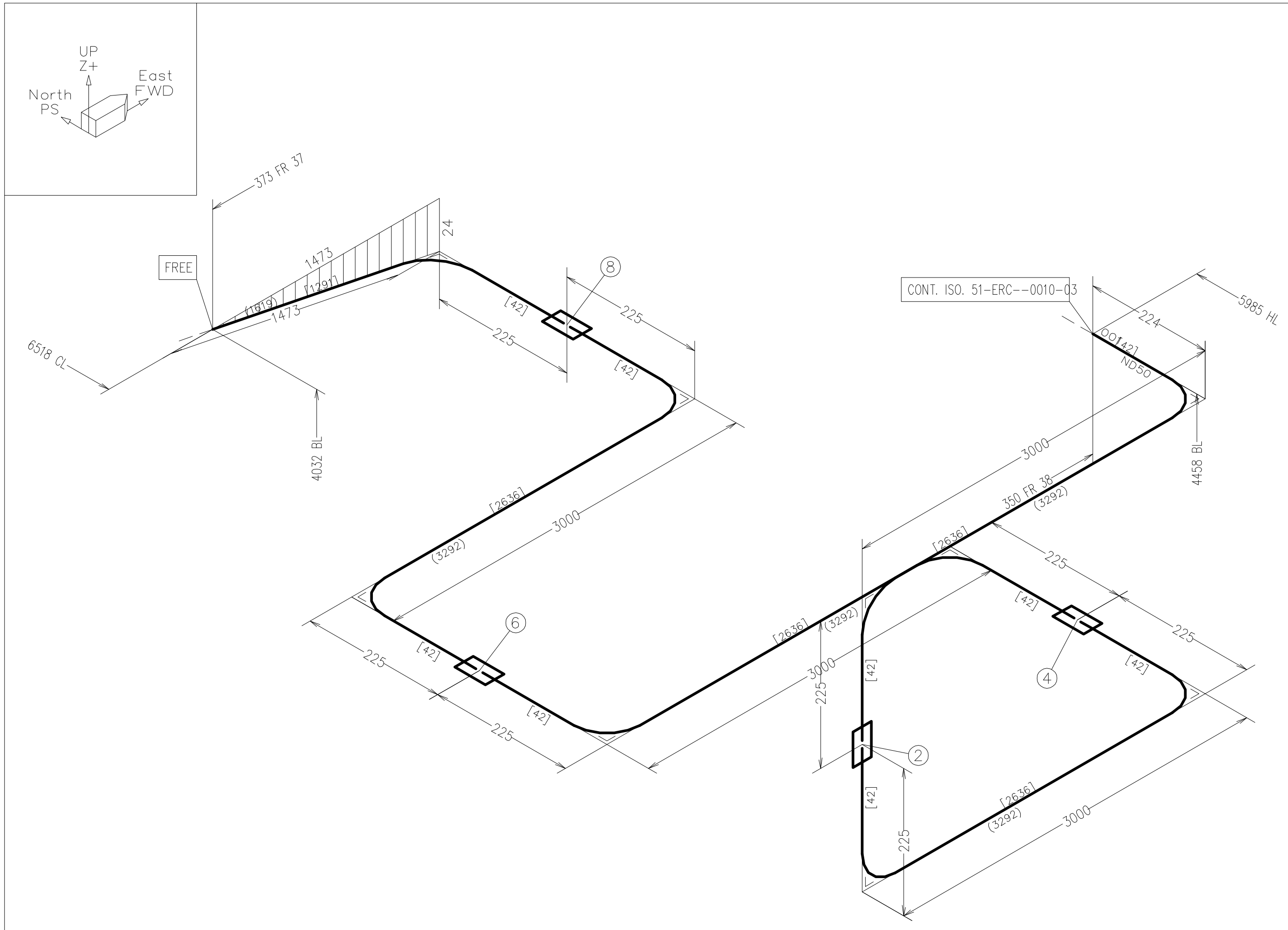
Tel : (62-778)472720, Fax :(62-778)472730

LINE NO. 001

PIPING ISOMETRIC
51038-001001
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	51038	050		01	0	



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
2	50			SLEEVE	SUS 316	10K	
3	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
4	50			SLEEVE	SUS 316	10K	
5	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
6	50			SLEEVE	SUS 316	10K	
7	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
8	50			SLEEVE	SUS 316	10K	
9	50		1.4	PIPE:NA -SUS 316	SUS 316		1619

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		14786
50			SLEEVE	SUS 316	10K	4

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-A5A1038-001002

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa – Batam Indonesia
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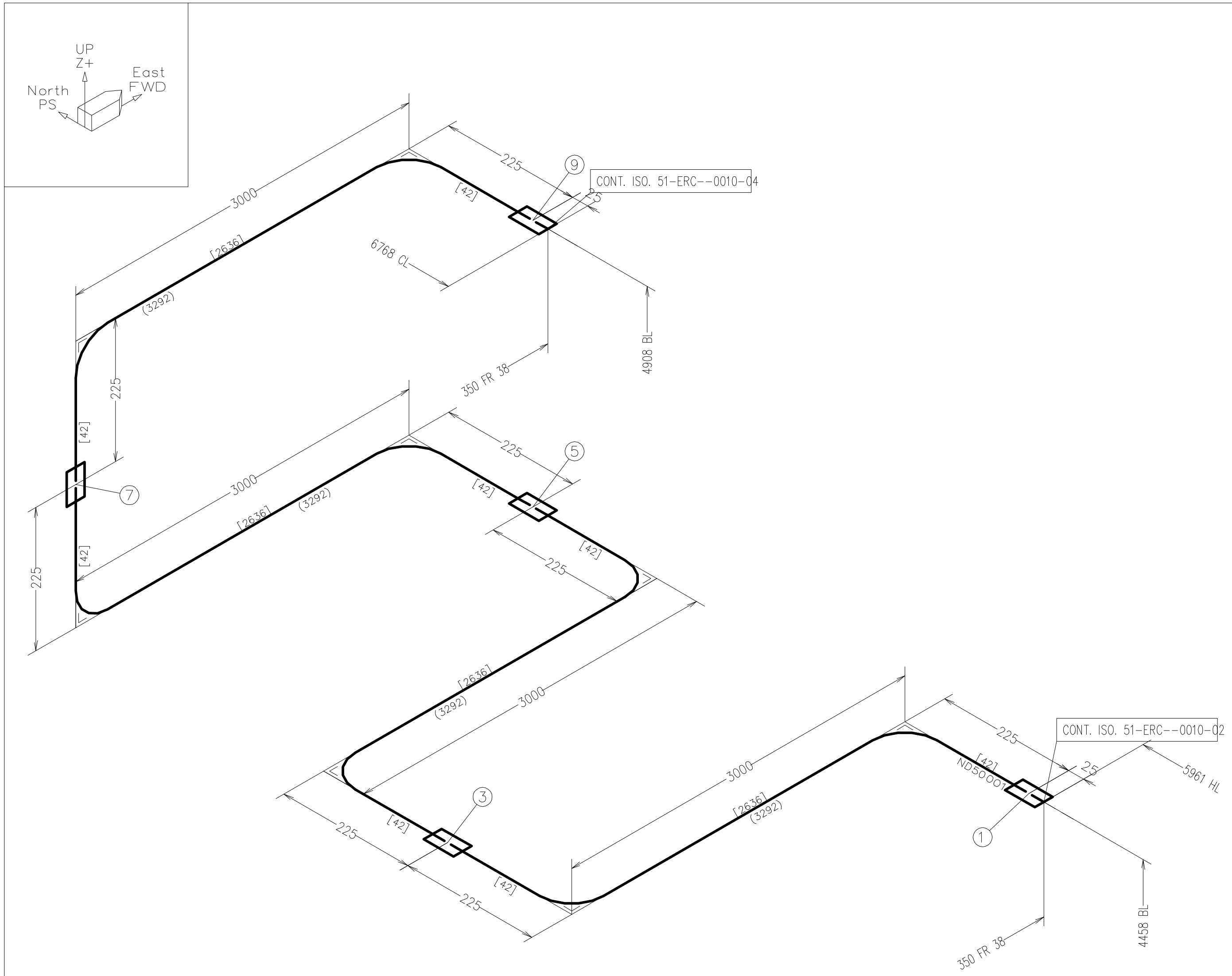
LINE NO. 001

PIPING ISOMETRIC
51038-001002
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	51038	050		02	0	



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50			SLEEVE	SUS 316	10K	
2	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
3	50			SLEEVE	SUS 316	10K	
4	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
5	50			SLEEVE	SUS 316	10K	
6	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
7	50			SLEEVE	SUS 316	10K	
8	50		1.4	PIPE:NA -SUS 316	SUS 316		3292
9	50			SLEEVE	SUS 316	10K	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		13167
50			SLEEVE	SUS 316	10K	5

SPOOL LIST

SPOOL NUMBER	WEIGHT
– –	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-A5A038-001003

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa – Batam Indonesia
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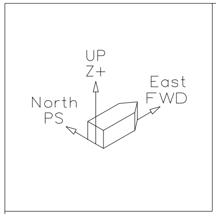
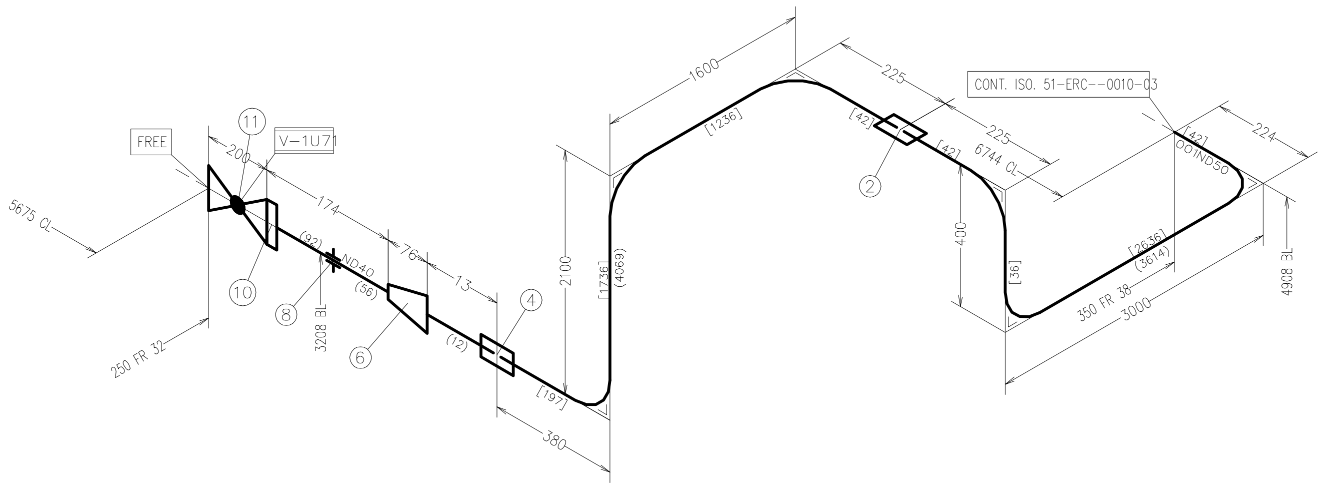
LINE NO. 001

PIPING ISOMETRIC
51038-001003
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	51038	050		03	0	





MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	50		1.4	PIPE:NA -SUS 316	SUS 316		3614
2	50			SLEEVE	SUS 316	10K	
3	50		1.4	PIPE:NA -SUS 316	SUS 316		4069
4	50			SLEEVE	SUS 316	10K	
5	50		1.4	PIPE:NA -SUS 316	SUS 316		12
6	50	40			STPG 370		
7	40		1.2	PIPE:NA -SUS 316	SUS 316		56
8	40			DOUBLER 10K	SS400	10K	
9	40		1.2	PIPE:NA -SUS 316	SUS 316		92
10	40			FLANGE	ROLLED STEEL	PN16	
11	40			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
50		1.4	PIPE:NA -SUS 316	SUS 316		7695
40		1.2	PIPE:NA -SUS 316	SUS 316		148
40			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	1
40			FLANGE	ROLLED STEEL	PN16	1
50			SLEEVE	SUS 316	10K	2
40			DOUBLER 10K	SS400	10K	1
50	40			STPG 370		1

SPOOL LIST

SPOOL NUMBER	WEIGHT
– –	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
01	13.03.15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-ASA1038-001004

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
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LINE NO. 001

PIPING ISOMETRIC
51038-001004
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	51038	050		04	0	

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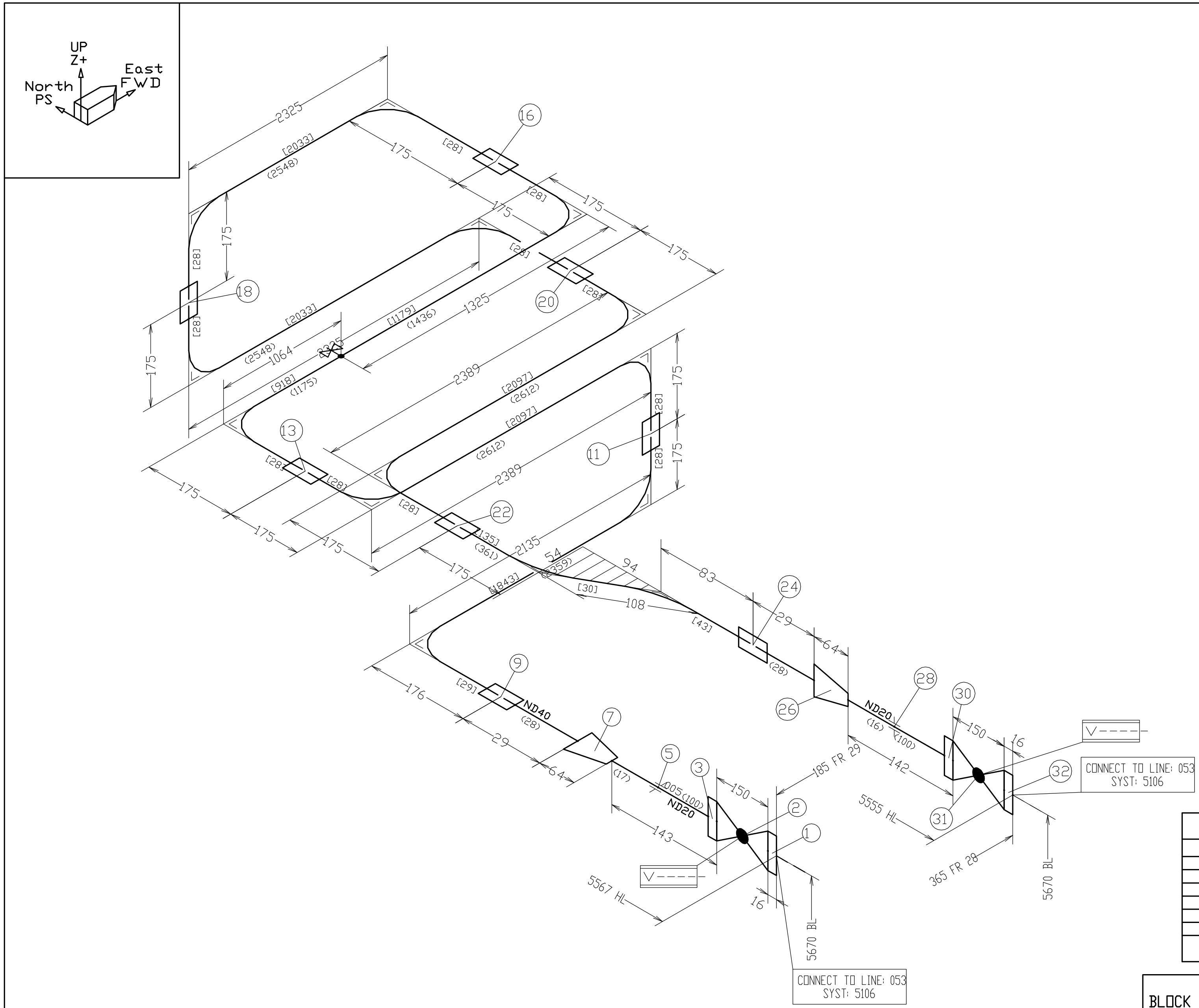
ATTACHMENT G
ISOMETRIC DRAWING OF HEATING COIL INSIDE SETTLING TANK



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	20			FLANGE	ROLLED STEEL	PN16	
2	20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
3	20			FLANGE	ROLLED STEEL	PN16	
4	20			PIPE:NA -SUS 316	SUS 316		100
5	20			DOUBLER 10K	SS400	16K	
6	20			PIPE:NA -SUS 316	SUS 316		17
7	40	20	5.1		STPG 370		
8	40			PIPE:NA -SUS 316	SUS 316		28
9	40			SLEEVE	SUS 316	10K	
10	40			PIPE:NA -SUS 316	SUS 316		2359
11	40			SLEEVE	SUS 316	10K	
12	40			PIPE:NA -SUS 316	SUS 316		2612
13	40			SLEEVE	SUS 316	10K	
14	40			PIPE:NA -SUS 316	SUS 316		1175
15	40			PIPE:NA -SUS 316	SUS 316		1436
16	40			SLEEVE	SUS 316	10K	
17	40			PIPE:NA -SUS 316	SUS 316		2548
18	40			SLEEVE	SUS 316	10K	
19	40			PIPE:NA -SUS 316	SUS 316		2548
20	40			SLEEVE	SUS 316	10K	
21	40			PIPE:NA -SUS 316	SUS 316		2612
22	40			SLEEVE	SUS 316	10K	
23	40			PIPE:NA -SUS 316	SUS 316		361
24	40			SLEEVE	SUS 316	10K	
25	40			PIPE:NA -SUS 316	SUS 316		28
26	40	20	5.1		STPG 370		
27	20			PIPE:NA -SUS 316	SUS 316		16
28	20			DOUBLER 10K	SS400	16K	
29	20			PIPE:NA -SUS 316	SUS 316		100
30	20			FLANGE	ROLLED STEEL	PN16	
31	20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
32	20			FLANGE	ROLLED STEEL	PN16	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
40			PIPE:NA -SUS 316	SUS 316		15707
20			PIPE:NA -SUS 316	SUS 316		234
20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	2
20			FLANGE	ROLLED STEEL	PN16	4
40			SLEEVE	SUS 316	10K	8
20			DOUBLER 10K	SS400	16K	2
40	20	5.1		STPG 370		2

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

BLOCK NO.

ISO NO. ERC-ASA-55038-005001

PT.ANGGREK HITAM SHIPYARD
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Kecamatan Nongsa - Batam Indonesia
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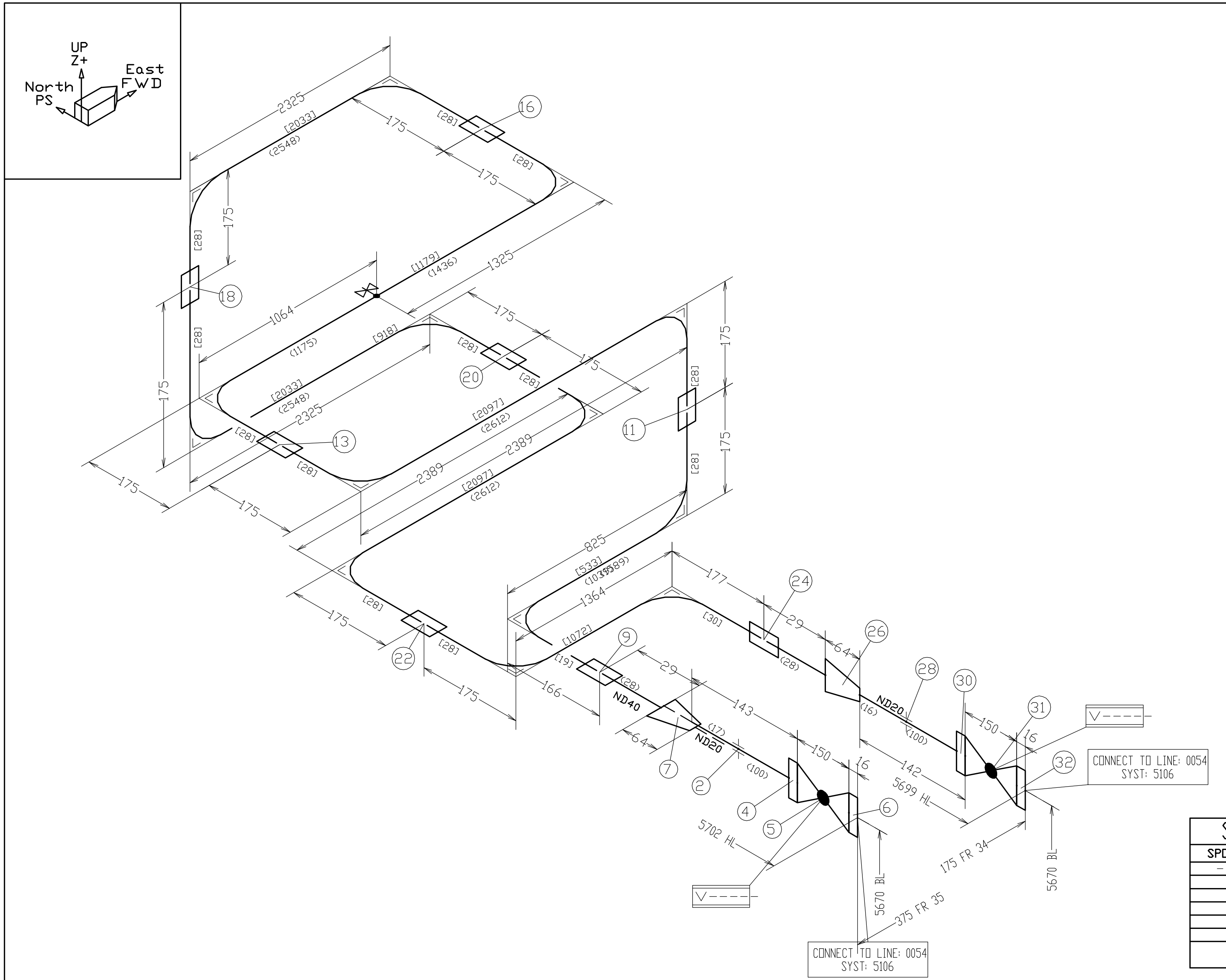
LINE NO. 005

PIPING ISOMETRIC
55038-005001
THERMAL OIL SYSTEM

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
0	05.11 .15	DESCRIPTION					

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	55038	040		01	0	

ATTACHMENT H
ISOMETRIC DRAWING OF HEATING COIL INSIDE SERVICE TANK PORTSIDE



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	20			PIPE:NA -SUS 316	SUS 316		17
2	20			DOUBLER 10K	SS400	16K	
3	20			PIPE:NA -SUS 316	SUS 316		100
4	20			FLANGE	ROLLED STEEL	PN16	
5	20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
6	20			FLANGE	ROLLED STEEL	PN16	
7	40	20	5.1		STPG 370		
8	40			PIPE:NA -SUS 316	SUS 316		28
9	40			SLEEVE	SUS 316	10K	
10	40			PIPE:NA -SUS 316	SUS 316		1039
11	40			SLEEVE	SUS 316	10K	
12	40			PIPE:NA -SUS 316	SUS 316		2612
13	40			SLEEVE	SUS 316	10K	
14	40			PIPE:NA -SUS 316	SUS 316		1175
15	40			PIPE:NA -SUS 316	SUS 316		1436
16	40			SLEEVE	SUS 316	10K	
17	40			PIPE:NA -SUS 316	SUS 316		2548
18	40			SLEEVE	SUS 316	10K	
19	40			PIPE:NA -SUS 316	SUS 316		2548
20	40			SLEEVE	SUS 316	10K	
21	40			PIPE:NA -SUS 316	SUS 316		2612
22	40			SLEEVE	SUS 316	10K	
23	40			PIPE:NA -SUS 316	SUS 316		1589
24	40			SLEEVE	SUS 316	10K	
25	40			PIPE:NA -SUS 316	SUS 316		28
26	40	20	5.1		STPG 370		
27	20			PIPE:NA -SUS 316	SUS 316		16
28	20			DOUBLER 10K	SS400	16K	
29	20			PIPE:NA -SUS 316	SUS 316		100
30	20			FLANGE	ROLLED STEEL	PN16	
31	20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
32	20			FLANGE	ROLLED STEEL	PN16	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
40			PIPE:NA -SUS 316	SUS 316		15615
20			PIPE:NA -SUS 316	SUS 316		234
20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	2
20			FLANGE	ROLLED STEEL	PN16	4
40			SLEEVE	SUS 316	10K	8
20			DOUBLER 10K	SS400	16K	2
40	20	5.1		STPG 370		2

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
0	05.11 .15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-ASA-55038-004001

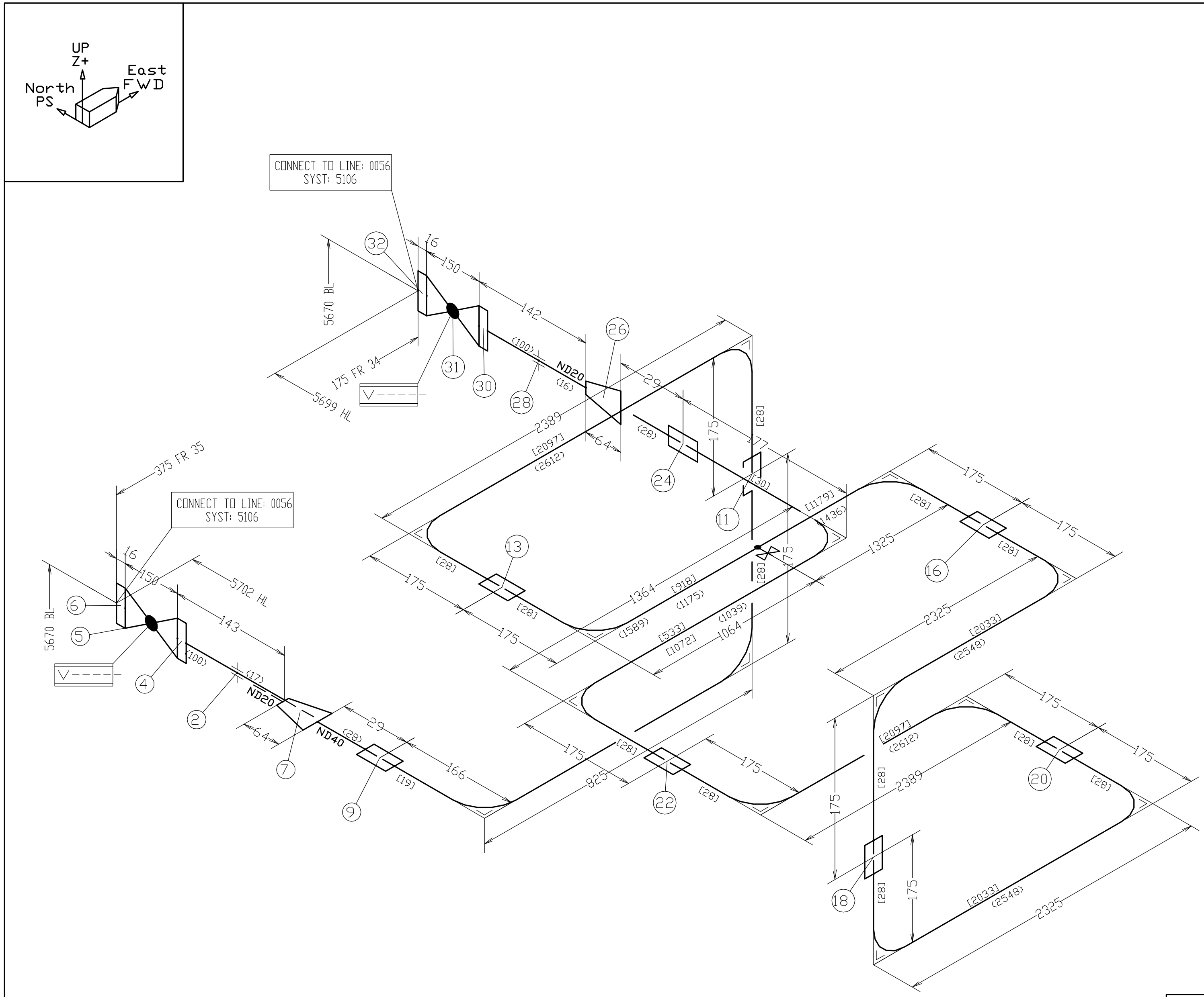
PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa - Batam Indonesia
Tel : (62-778)472720, Fax :(62-778)472730

LINE NO. 004

PIPING ISOMETRIC
55038-004001
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	55038	040		01	0	

ATTACHMENT I
ISOMETRIC DRAWING OF HEATING COIL INSIDE SERVICE TANK STARBOARD



MATERIAL LIST

POS. NO.	N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	CUT LENGTH
1	20			PIPE:NA -SUS 316	SUS 316		17
2	20			DOUBLER 10K	SS400	16K	
3	20			PIPE:NA -SUS 316	SUS 316		100
4	20			FLANGE	ROLLED STEEL	PN16	
5	20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
6	20			FLANGE	ROLLED STEEL	PN16	
7	40	20	5.1		STPG 370		
8	40			PIPE:NA -SUS 316	SUS 316		28
9	40			SLEEVE	SUS 316	10K	
10	40			PIPE:NA -SUS 316	SUS 316		1039
11	40			SLEEVE	SUS 316	10K	
12	40			PIPE:NA -SUS 316	SUS 316		2612
13	40			SLEEVE	SUS 316	10K	
14	40			PIPE:NA -SUS 316	SUS 316		1175
15	40			PIPE:NA -SUS 316	SUS 316		1436
16	40			SLEEVE	SUS 316	10K	
17	40			PIPE:NA -SUS 316	SUS 316		2548
18	40			SLEEVE	SUS 316	10K	
19	40			PIPE:NA -SUS 316	SUS 316		2548
20	40			SLEEVE	SUS 316	10K	
21	40			PIPE:NA -SUS 316	SUS 316		2612
22	40			SLEEVE	SUS 316	10K	
23	40			PIPE:NA -SUS 316	SUS 316		1589
24	40			SLEEVE	SUS 316	10K	
25	40			PIPE:NA -SUS 316	SUS 316		28
26	40	20	5.1		STPG 370		
27	20			PIPE:NA -SUS 316	SUS 316		16
28	20			DOUBLER 10K	SS400	16K	
29	20			PIPE:NA -SUS 316	SUS 316		100
30	20			FLANGE	ROLLED STEEL	PN16	
31	20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	
32	20			FLANGE	ROLLED STEEL	PN16	

MATERIAL SUMMARY

N.D.	S.D. ANG.	THK.	DESCRIPTION	MATERIAL QUALITY	RATING	QTY/L
20			PIPE:NA -SUS 316	SUS 316		234
40			PIPE:NA -SUS 316	SUS 316		15615
20			GLOBE STOP VALVE WITH BELOW	CAST IRON	PN16	2
20			FLANGE	ROLLED STEEL	PN16	4
20			DOUBLER 10K	SS400	16K	2
40			SLEEVE	SUS 316	10K	8
40	20	5.1		STPG 370		2

SPOOL LIST

SPOOL NUMBER	WEIGHT
- -	
Total Weight	

GASKETS, BOLTS AND NUTS

QTY.	ND	DESCRIPTION	MATERIAL QUALITY	METRIC	LENGTH

REV	ISSUE DATE	DESCRIPTION	REF. NO	DRAWN BY	CHK'D BY	APPR. DISC.	APPR. CONTR.
0	05.11 .15	DESCRIPTION					

BLOCK NO.

ISO NO. ERC-ASA-55038-006001

PT.ANGGREK HITAM SHIPYARD
Jl. Raya Pelabuhan Kabil, Kelurahan Kabil
Kecamatan Nongsa - Batam Indonesia
Tel : (62-778)472720, Fax :(62-778)472730

LINE NO. 006

PIPING ISOMETRIC

55038-006001
THERMAL OIL SYSTEM

SCALE	SIZE	SYST. CODE	ND	DOCUMENT NO.	SHEET	REV	STATUS
ISO	A3	55038	040		01	0	

ATTACHMENT J
ECONOMIZER ANALYSIS CALCULATION

Economizer Analysis on Thermal Oil Heating Process

Economizer analysis on thermal oil process means to prove is done because there are differences data between the maker's data with the shop test data of the main engine.
The following table will show the technical data of economizer, thermal oil fluid, and shop trial record of main engine used.

Technical Data of Economizer				Thermal Oil Fluid Specification			
Type	=	Aalborg EXV632 46 48.3 900DD		**Type**	=	Therminol 66	
Quantity	=	23,7	m^3/h	**Composition**	=	Hydrogenated Terphenyl	
T_{inlet}	=	140	^oC	**Kinematic Vis. (40^oC)**	=	29,64	cSt
T_{Outlet}	=	180	^oC				
Flow Resistance	=	17,5	m.l.c	**Density (15^oC)**	=	1011	kg/m^3
Diameter Without Insulation	=	1664	mm	**Flash Point**	=	170	^oC
				Fire Point	=	216	^oC
Weight (Empty)	=	6200	kg	**Total Acidity**	=	<0,02	mgKOH/g
Liquid Contents	=	1190	Litres	**Pour Point**	=	-32	^oC

Shop Trial Record of Main Engine on MT. Parigi					
Engine Load (%)	**Engine Output (kW)**	**Exh. Gas T/C Inlet (^oC)**	**Exh. Gas T/C Outlet (^oC)**	**Specific Heat of Exh. Gas (kJ/kgK)**	**Exhaust Gas Amount (kg/h)**
75%	3330	365	225	1,030	21670
85%	3774	380	225	1,030	26862
100%	4440	420	240	1,033	35757

Engine load 85 (%)

- Capacity:..500 kW
- Exhaust gas quantity:..33.300 kg/h
- Exhaust gas temperature before heater..248 °C
- Exhaust gas temperature after heater...197 °C
- Pressure drop exhaust gasses...1.232 Pa.

Engine load 100 (%)

- Capacity:..619 kW
- Exhaust gas quantity:..37.200kg/h
- Exhaust gas temperature before heater..265 °C
- Exhaust gas temperature after heater...209 °C
- Pressure drop exhaust gasses...1.545 Pa.

Therefore, the analysis will be done in order to find out the outlet temperature of exhaust gas from the economizer, at 75%, 85%, and 100% MCR of the main engine.

Analysis on 75% Load of Main Engine

Heat of thermal oil fluid will be kept constant. The heat value of thermal oil fluid is as following.

$$Q_{TO} = m_{TO} \times Cp_{TO} \times \Delta T_{TO}$$
$$= 483{,}162 \text{ kW}$$

Then, find out the outlet temperature of exhaust gas from the economizer.

$$Q_{TO} = Q_{EG}$$
$$T_{EGout} = 420{,}196 \text{ K}$$
$$= 147{,}046\ ^{o}C$$

Based on calculation above, it is known that the outlet temperature of exhaust gas from the economizer at 75% load of main engine is 151,72 ^{o}C.

Analysis on 85% Load of Main Engine

Heat of thermal oil fluid will be kept constant. The heat value of thermal oil fluid is as following.

$$Q_{TO} = m_{TO} \times Cp_{TO} \times \Delta T_{TO}$$
$$= 483{,}162 \text{ kW}$$

Then, find out the outlet temperature of exhaust gas from the economizer.

$$Q_{TO} = Q_{EG}$$
$$T_{EGout} = 435{,}264 \text{ K}$$
$$= 162{,}114\ ^{o}C$$

Based on calculation above, it is known that the outlet temperature of exhaust gas from the economizer at 85% load of main engine is 166,5 ^{o}C.

Analysis on 100% Load of Main Engine

Heat of thermal oil fluid will be kept constant. The heat value of thermal oil fluid is as following.

$$Q_{TO} = m_{TO} \times Cp_{TO} \times \Delta T_{TO}$$

$$= 483{,}162 \text{ kW}$$

Then, find out the outlet temperature of exhaust gas from the economizer.

$$Q_{TO} = Q_{EG}$$

$$T_{EGout} = 466{,}048 \text{ K}$$

$$= 192{,}898 \ ^{o}C$$

Based on calculation above, it is known that the outlet temperature of exhaust gas from the economizer at 85% load of main engine is 196,3 ^{o}C.

ATTACHMENT K
HEAT LOSSES ANALYSIS CALCULATION IN BOILER SCENARIO

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Boiler - Distribution Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	150A	
Schedule	:	80	
Outside Diameter	:	165,2	mm
Inner Diameter	:	154,2	mm
Thickness	:	11	mm
Total Length	:	9764	mm
	:	9,764	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	30	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	180	^{o}C
	:	453,15	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,053202743	K.m/W
R2 (Oil Conduction)	:	0,000329004	K.m/W
R3 (Insulation Cond.)	:	0,479383344	K.m/W
R4 (Air Convection)	:	3,26137E-02	K.m/W
Total Resistance	**:**	**0,565528809**	**K.m/W**
	:	**238,7146292**	**W/m**
Q_{LOSS}	**:**	**0,238714629**	**kW/m**
	:	**2,330809639**	**kW**
Temperature Decrease	**:**	**453,12**	**K**
	:	**179,97**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Branch Pipe (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	12389	mm
	:	12,389	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,97	^{o}C
	:	453,12	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,530705**	**W/m**
Q_{LOSS}	**:**	**0,135530705**	**kW/m**
	:	**1,679089904**	**kW**
Temperature Decrease	**:**	**453,10**	**K**
	:	**179,95**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (P) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	18430	mm
	:	18,43	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,95	^{o}C
	:	453,10	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,5112557**	**W/m**
Q_{LOSS}	**:**	**0,135511256**	**kW/m**
	:	**2,497472443**	**kW**
Temperature Decrease	**:**	**453,07**	**K**
	:	**179,92**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (P) (40A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	3901	mm
	:	3,901	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,92	^{o}C
	:	453,07	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,00052933	K.m/W
R3 (Insulation Cond.)	:	1,192287408	K.m/W
R4 (Air Convection)	:	8,64973E-02	K.m/W
Total Resistance	**:**	**1,467908542**	**K.m/W**
Q_{LOSS}	**:**	**91,9164444**	**W/m**
	:	**0,091916444**	**kW/m**
	:	**0,35856605**	**kW**
Temperature Decrease	**:**	**453,07**	**K**
	:	**179,92**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (S) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	22887	mm
	:	22,887	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,95	^{o}C
	:	453,10	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,5112557**	**W/m**
Q_{LOSS}	**:**	**0,135511256**	**kW/m**
	:	**3,10144611**	**kW**
Temperature Decrease	**:**	**453,07**	**K**
	:	**179,92**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (S) (40A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	2502	mm
	:	2,502	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,92	^oC
	:	453,07	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,00052933	K.m/W
R3 (Insulation Cond.)	:	1,192287408	K.m/W
R4 (Air Convection)	:	8,64973E-02	K.m/W
Total Resistance	**:**	**1,467908542**	**K.m/W**
Q_{LOSS}	**:**	**91,91169808**	**W/m**
	:	**0,091911698**	**kW/m**
	:	**0,229963069**	**kW**
Temperature Decrease	**:**	**453,07**	**K**
	:	**179,92**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Settling Tank (P) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	12121	mm
	:	12,121	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,95	^{o}C
	:	453,10	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,5112557**	**W/m**
Q_{LOSS}	**:**	**0,135511256**	**kW/m**
	:	**1,642531931**	**kW**
Temperature Decrease	**:**	**453,08**	**K**
	:	**179,93**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Settling Tank (P) (20A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	11363	mm
	:	11,363	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,93	^oC
	:	453,08	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000738942	K.m/W
R3 (Insulation Cond.)	:	1,583439192	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,07115233**	**K.m/W**
Q_{LOSS}	**:**	**65,14962426**	**W/m**
	:	**0,065149624**	**kW/m**
	:	**0,74029518**	**kW**
Temperature Decrease	**:**	**453,08**	**K**
	:	**179,93**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (P) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	12425	mm
	:	12,425	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,95	^{o}C
	:	453,10	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
Q_{LOSS}	**:**	**135,5112557**	**W/m**
	:	**0,135511256**	**kW/m**
	:	**1,683727353**	**kW**
Temperature Decrease	**:**	**453,08**	**K**
	:	**179,93**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (P) (20A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	12215	mm
	:	12,215	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,93	^{o}C
	:	453,08	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000738942	K.m/W
R3 (Insulation Cond.)	:	1,583439192	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,07115233**	**K.m/W**
Q_{LOSS}	**:**	**65,14939482**	**W/m**
	:	**0,065149395**	**kW/m**
	:	**0,795799858**	**kW**
Temperature Decrease	**:**	**453,08**	**K**
	:	**179,93**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (S) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	19747	mm
	:	19,747	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,95	^{o}C
	:	453,10	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,5112557**	**W/m**
Q_{LOSS}	**:**	**0,135511256**	**kW/m**
	:	**2,675940767**	**kW**
Temperature Decrease	**:**	**453,07**	**K**
	:	**179,92**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (S) (20A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	11241	mm
	:	11,241	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,92	^{o}C
	:	453,07	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000738942	K.m/W
R3 (Insulation Cond.)	:	1,583439192	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,07115233**	**K.m/W**
	:	**65,14386856**	**W/m**
Q_{LOSS}	**:**	**0,065143869**	**kW/m**
	:	**0,732282226**	**kW**
Temperature Decrease	**:**	**453,06**	**K**
	:	**179,91**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (S) (20A) - (60A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	10450	mm
	:	10,45	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^{o}C
	:	413,21	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000724453	K.m/W
R3 (Insulation Cond.)	:	1,804990354	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,292689004**	**K.m/W**
Q_{LOSS}	**:**	**41,46223052**	**W/m**
	:	**0,041462231**	**kW/m**
	:	**0,433280309**	**kW**
Temperature Decrease	**:**	**413,20**	**K**
	:	**140,05**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (S) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	20839	mm
	:	20,839	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,05	^{o}C
	:	413,2048004	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**100,3431897**	**W/m**
Q_{LOSS}	**:**	**0,10034319**	**kW/m**
	:	**2,09105173**	**kW**
Temperature Decrease	**:**	**413,18**	**K**
	:	**140,03**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (P) (20A) - (60A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	12919	mm
	:	12,919	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^{o}C
	:	413,21	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000724453	K.m/W
R3 (Insulation Cond.)	:	1,804990354	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,292689004**	**K.m/W**
	:	**41,46223052**	**W/m**
Q_{LOSS}	**:**	**0,041462231**	**kW/m**
	:	**0,535650556**	**kW**
Temperature Decrease	**:**	**413,20**	**K**
	:	**140,05**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (P) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	20661	mm
	:	20,661	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,05	^oC
	:	413,2035719	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**100,3418929**	**W/m**
Q_{LOSS}	**:**	**0,100341893**	**kW/m**
	:	**2,073163848**	**kW**
Temperature Decrease	**:**	**413,18**	**K**
	:	**140,03**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Settling Tank (P) (20A) - (60A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	11840	mm
	:	11,84	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^oC
	:	413,21	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000724453	K.m/W
R3 (Insulation Cond.)	:	1,804990354	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,292689004**	**K.m/W**
	:	**41,46223052**	**W/m**
Q_{LOSS}	**:**	**0,041462231**	**kW/m**
	:	**0,490912809**	**kW**
Temperature Decrease	**:**	**413,20**	**K**
	:	**140,05**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Settling Tank (P) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	20333	mm
	:	20,333	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,05	^{o}C
	:	413,2041088	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**100,3424596**	**W/m**
Q_{LOSS}	**:**	**0,10034246**	**kW/m**
	:	**2,040263231**	**kW**
Temperature Decrease	**:**	**413,18**	**K**
	:	**140,03**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (S) (40A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	2674	mm
	:	2,674	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^oC
	:	413,21	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,000518951	K.m/W
R3 (Insulation Cond.)	:	1,128719664	K.m/W
R4 (Air Convection)	:	9,28017E-02	K.m/W
Total Resistance	**:**	**1,410634884**	**K.m/W**
	:	**67,38809671**	**W/m**
Q_{LOSS}	**:**	**0,067388097**	**kW/m**
	:	**0,180195771**	**kW**
Temperature Decrease	**:**	**413,21**	**K**
	:	**140,06**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution
Scenario = Storage Tank (S) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	26223	mm
	:	26,223	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^{o}C
	:	413,2078376	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**100,3463958**	**W/m**
Q_{LOSS}	**:**	**0,100346396**	**kW/m**
	:	**2,631383537**	**kW**
Temperature Decrease	**:**	**413,18**	**K**
	:	**140,03**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (P) (40A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	4089	mm
	:	4,089	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^oC
	:	413,21	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,000518951	K.m/W
R3 (Insulation Cond.)	:	1,128719664	K.m/W
R4 (Air Convection)	:	9,28017E-02	K.m/W
Total Resistance	**:**	**1,410634884**	**K.m/W**
Q_{LOSS}	**:**	**67,38809671**	**W/m**
	:	**0,067388097**	**kW/m**
	:	**0,275549927**	**kW**
Temperature Decrease	**:**	**413,21**	**K**
	:	**140,06**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (P) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	19699	mm
	:	19,699	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,06	^{o}C
	:	413,2066933	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
Q_{LOSS}	**:**	**100,3451878**	**W/m**
	:	**0,100345188**	**kW/m**
	:	**1,976699855**	**kW**
Temperature Decrease	**:**	**413,18**	**K**
	:	**140,03**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution
Scenario = Consumer Line (65A) - Distribution Line (150A)

Pipe Parameters			
Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	14359	mm
	:	14,359	m
Insulation Parameters			
Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK
Temperature Parameters			
Fluid Temperature	:	140,03	^{o}C
	:	413,182972	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K
Heat Loss Analysis			
R1 (Oil Convection)	:	0,11838186	K.m/W
R2 (Oil Conduction)	:	0,00045045	K.m/W
R3 (Insulation Cond.)	:	0,7623567	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,94729698**	**K.m/W**
Q_{LOSS}	**:**	**100,320147**	**W/m**
	:	**0,10032015**	**kW/m**
	:	**1,44049699**	**kW**
Temperature Decrease	**:**	**413,17**	**K**
	:	**140,02**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Distribution Line (150A) - Deaerated Pipe

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	150A	
Schedule	:	80	
Outside Diameter	:	165,2	mm
Inner Diameter	:	154,2	mm
Thickness	:	11	mm
Total Length	:	8031	mm
	:	8,031	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,02	^{o}C
	:	413,165685	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,05320274	K.m/W
R2 (Oil Conduction)	:	0,00032255	K.m/W
R3 (Insulation Cond.)	:	0,37424159	K.m/W
R4 (Air Convection)	:	3,43747E-02	K.m/W
Total Resistance	**:**	**0,4621416**	**K.m/W**
Q_{LOSS}	**:**	**205,598641**	**W/m**
	:	**0,20559864**	**kW/m**
	:	**1,65116269**	**kW**
Temperature Decrease	**:**	**413,15**	**K**
	:	**140,00**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Suction of Boiler Pump from Deaerated Pipe

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	200A	
Schedule	:	80	
Outside Diameter	:	216,3	mm
Inner Diameter	:	203,6	mm
Thickness	:	12,7	mm
Total Length	:	14960	mm
	:	14,96	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,00	^{o}C
	:	413,15	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,040294023	K.m/W
R2 (Oil Conduction)	:	0,000283245	K.m/W
R3 (Insulation Cond.)	:	0,358179312	K.m/W
R4 (Air Convection)	:	2,63829E-02	K.m/W
Total Resistance	**:**	**0,425139496**	**K.m/W**
	:	**223,446355**	**W/m**
Q_{LOSS}	**:**	**0,223446355**	**kW/m**
	:	**3,342757471**	**kW**
Temperature Decrease	**:**	**413,11**	**K**
	:	**139,96**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Goes to Boiler from Pump

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	150A	
Schedule	:	80	
Outside Diameter	:	165,2	mm
Inner Diameter	:	154,2	mm
Thickness	:	11	mm
Total Length	:	23581	mm
	:	23,581	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	139,96	^{o}C
	:	413,11	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,053202743	K.m/W
R2 (Oil Conduction)	:	0,000322553	K.m/W
R3 (Insulation Cond.)	:	0,374241587	K.m/W
R4 (Air Convection)	:	3,43747E-02	K.m/W
Total Resistance	**:**	**0,462141601**	**K.m/W**
	:	**205,4689641**	**W/m**
Q_{LOSS}	**:**	**0,205468964**	**kW/m**
	:	**4,845163643**	**kW**
Temperature Decrease	**:**	**413,05**	**K**
	:	**139,90**	**^{o}C**

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ATTACHMENT L
HEAT LOSSES ANALYSIS CALCULATION IN ECONOMIZER SCENARIO

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Economizer - Distribution Line (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	14602	mm
	:	14,602	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	180	^{o}C
	:	453,15	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,5577032**	**W/m**
Q_{LOSS}	**:**	**0,135557703**	**kW/m**
	:	**1,979413582**	**kW**
Temperature Decrease	**:**	**452,99**	**K**
	:	**179,84**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Economizer - Distribution Line (125A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	125A	
Schedule	:	80	
Outside Diameter	:	139,8	mm
Inner Diameter	:	130,3	mm
Thickness	:	9,5	mm
Total Length	:	322	mm
	:	0,322	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	30	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,84	^{o}C
	:	452,9924769	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,062961343	K.m/W
R2 (Oil Conduction)	:	0,000336008	K.m/W
R3 (Insulation Cond.)	:	0,558502976	K.m/W
R4 (Air Convection)	:	3,74923E-02	K.m/W
Total Resistance	**:**	**0,659292658**	**K.m/W**
Q_{LOSS}	**:**	**204,52598**	**W/m**
	:	**0,20452598**	**kW/m**
	:	**0,065857366**	**kW**
Temperature Decrease	**:**	**452,99**	**K**
	:	**179,84**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Economizer - Distribution Line (150A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	150A	
Schedule	:	80	
Outside Diameter	:	165,2	mm
Inner Diameter	:	154,2	mm
Thickness	:	11	mm
Total Length	:	4797	mm
	:	4,797	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	30	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,84	^{o}C
	:	452,987236	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^{2}K
Oil Convection Coeff.	:	38,8	W/m^{2}K

Heat Loss Analysis

R1 (Oil Convection)	:	0,053202743	K.m/W
R2 (Oil Conduction)	:	0,000329004	K.m/W
R3 (Insulation Cond.)	:	0,479383344	K.m/W
R4 (Air Convection)	:	3,26137E-02	K.m/W
Total Resistance	**:**	**0,565528809**	**K.m/W**
Q_{LOSS}	**:**	**238,4268206**	**W/m**
	:	**0,238426821**	**kW/m**
	:	**1,143733458**	**kW**
Temperature Decrease	**:**	**452,90**	**K**
	:	**179,75**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Branch Pipe (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	12389	mm
	:	12,389	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,75	^{o}C
	:	452,90	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,3028717**	**W/m**
Q_{LOSS}	**:**	**0,135302872**	**kW/m**
	:	**1,676267277**	**kW**
Temperature Decrease	**:**	**452,76**	**K**
	:	**179,61**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (P) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	18430	mm
	:	18,43	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,61	^{o}C
	:	452,76	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,1689221**	**W/m**
Q_{LOSS}	**:**	**0,135168922**	**kW/m**
	:	**2,491163235**	**kW**
Temperature Decrease	**:**	**452,56**	**K**
	:	**179,41**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (P) (40A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	3901	mm
	:	3,901	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,41	^{o}C
	:	452,56	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,00052933	K.m/W
R3 (Insulation Cond.)	:	1,192287408	K.m/W
R4 (Air Convection)	:	8,64973E-02	K.m/W
Total Resistance	**:**	**1,467908542**	**K.m/W**
Q_{LOSS}	**:**	**91,56876338**	**W/m**
	:	**0,091568763**	**kW/m**
	:	**0,357209746**	**kW**
Temperature Decrease	**:**	**452,54**	**K**
	:	**179,39**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (S) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	22887	mm
	:	22,887	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,61	^{o}C
	:	452,76	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,1689221**	**W/m**
Q_{LOSS}	**:**	**0,135168922**	**kW/m**
	:	**3,093611121**	**kW**
Temperature Decrease	**:**	**452,52**	**K**
	:	**179,37**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Storage Tank (S) (40A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	2502	mm
	:	2,502	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,37	^{o}C
	:	452,52	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,00052933	K.m/W
R3 (Insulation Cond.)	:	1,192287408	K.m/W
R4 (Air Convection)	:	8,64973E-02	K.m/W
Total Resistance	**:**	**1,467908542**	**K.m/W**
Q_{LOSS}	**:**	**91,53610248**	**W/m**
	:	**0,091536102**	**kW/m**
	:	**0,229023328**	**kW**
Temperature Decrease	**:**	**452,50**	**K**
	:	**179,35**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Settling Tank (P) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	12121	mm
	:	12,121	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,61	^{o}C
	:	452,76	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,1689221**	**W/m**
Q_{LOSS}	**:**	**0,135168922**	**kW/m**
	:	**1,638382505**	**kW**
Temperature Decrease	**:**	**452,63**	**K**
	:	**179,48**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Settling Tank (P) (20A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	11363	mm
	:	11,363	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,48	^{o}C
	:	452,63	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000738942	K.m/W
R3 (Insulation Cond.)	:	1,583439192	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,07115233**	**K.m/W**
	:	**64,93121382**	**W/m**
Q_{LOSS}	**:**	**0,064931214**	**kW/m**
	:	**0,737813383**	**kW**
Temperature Decrease	**:**	**452,57**	**K**
	:	**179,42**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (P) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	12425	mm
	:	12,425	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,61	^{o}C
	:	452,76	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,1689221**	**W/m**
Q_{LOSS}	**:**	**0,135168922**	**kW/m**
	:	**1,679473857**	**kW**
Temperature Decrease	**:**	**452,63**	**K**
	:	**179,48**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (P) (20A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	12215	mm
	:	12,215	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,48	^{o}C
	:	452,63	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000738942	K.m/W
R3 (Insulation Cond.)	:	1,583439192	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,07115233**	**K.m/W**
	:	**64,92963495**	**W/m**
Q_{LOSS}	**:**	**0,064929635**	**kW/m**
	:	**0,793115491**	**kW**
Temperature Decrease	**:**	**452,57**	**K**
	:	**179,42**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (S) (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	19747	mm
	:	19,747	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	25	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,61	^{o}C
	:	452,76	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000459455	K.m/W
R3 (Insulation Cond.)	:	0,814199552	K.m/W
R4 (Air Convection)	:	6,28450E-02	K.m/W
Total Resistance	**:**	**0,995885861**	**K.m/W**
	:	**135,1689221**	**W/m**
Q_{LOSS}	**:**	**0,135168922**	**kW/m**
	:	**2,669180705**	**kW**
Temperature Decrease	**:**	**452,55**	**K**
	:	**179,40**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line - Service Tank (S) (20A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	33,33	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	11241	mm
	:	11,241	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0554	W/mK

Temperature Parameters

Fluid Temperature	:	179,40	^{o}C
	:	452,55	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000738942	K.m/W
R3 (Insulation Cond.)	:	1,583439192	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,07115233**	**K.m/W**
	:	**64,89160707**	**W/m**
Q_{LOSS}	**:**	**0,064891607**	**kW/m**
	:	**0,729446555**	**kW**
Temperature Decrease	**:**	**452,49**	**K**
	:	**179,34**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (S) (20A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	10450	mm
	:	10,45	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,76	^{o}C
	:	413,91	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000724453	K.m/W
R3 (Insulation Cond.)	:	1,804990354	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,292689004**	**K.m/W**
	:	**41,76754886**	**W/m**
Q_{LOSS}	**:**	**0,041767549**	**kW/m**
	:	**0,436470886**	**kW**
Temperature Decrease	**:**	**413,87**	**K**
	:	**140,72**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (S) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	20839	mm
	:	20,839	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,72	^{o}C
	:	413,8738655	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**101,0494783**	**W/m**
Q_{LOSS}	**:**	**0,101049478**	**kW/m**
	:	**2,105770078**	**kW**
Temperature Decrease	**:**	**413,70**	**K**
	:	**140,55**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (P) (20A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	12919	mm
	:	12,919	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,68	^{o}C
	:	413,83	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000724453	K.m/W
R3 (Insulation Cond.)	:	1,804990354	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,292689004**	**K.m/W**
	:	**41,73265534**	**W/m**
Q_{LOSS}	**:**	**0,041732655**	**kW/m**
	:	**0,539144174**	**kW**
Temperature Decrease	**:**	**413,79**	**K**
	:	**140,64**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Service Tank (P) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	20661	mm
	:	20,661	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,64	^{o}C
	:	413,7853654	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
Q_{LOSS}	**:**	**100,9560544**	**W/m**
	:	**0,100956054**	**kW/m**
	:	**2,085853041**	**kW**
Temperature Decrease	**:**	**413,61**	**K**
	:	**140,46**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Settling Tank (P) (20A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	20A	
Schedule	:	80	
Outside Diameter	:	27,2	mm
Inner Diameter	:	23,3	mm
Thickness	:	3,9	mm
Total Length	:	11840	mm
	:	11,84	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,68	^{o}C
	:	413,83	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,352097126	K.m/W
R2 (Oil Conduction)	:	0,000724453	K.m/W
R3 (Insulation Cond.)	:	1,804990354	K.m/W
R4 (Air Convection)	:	1,34877E-01	K.m/W
Total Resistance	**:**	**2,292689004**	**K.m/W**
Q_{LOSS}	**:**	**41,73265534**	**W/m**
	:	**0,041732655**	**kW/m**
	:	**0,494114639**	**kW**
Temperature Decrease	**:**	**413,79**	**K**
	:	**140,64**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Settling Tank (P) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	20333	mm
	:	20,333	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,64	^{o}C
	:	413,7890933	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
Q_{LOSS}	**:**	**100,9599897**	**W/m**
	:	**0,10095999**	**kW/m**
	:	**2,052819472**	**kW**
Temperature Decrease	**:**	**413,62**	**K**
	:	**140,47**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (S) (40A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	2674	mm
	:	2,674	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,74	^{o}C
	:	413,89	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,000518951	K.m/W
R3 (Insulation Cond.)	:	1,128719664	K.m/W
R4 (Air Convection)	:	9,28017E-02	K.m/W
Total Resistance	**:**	**1,410634884**	**K.m/W**
Q_{LOSS}	**:**	**67,87014916**	**W/m**
	:	**0,067870149**	**kW/m**
	:	**0,181484779**	**kW**
Temperature Decrease	**:**	**413,87**	**K**
	:	**140,72**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (S) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	26223	mm
	:	26,223	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,72	^{o}C
	:	413,8749752	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**101,0506498**	**W/m**
Q_{LOSS}	**:**	**0,10105065**	**kW/m**
	:	**2,649851189**	**kW**
Temperature Decrease	**:**	**413,66**	**K**
	:	**140,51**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (P) (40A) - (65A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	40A	
Schedule	:	80	
Outside Diameter	:	48,6	mm
Inner Diameter	:	43,5	mm
Thickness	:	5,1	mm
Total Length	:	4089	mm
	:	4,089	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,71	^oC
	:	413,86	K
Ambient Temperature	:	45	^oC
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,188594553	K.m/W
R2 (Oil Conduction)	:	0,000518951	K.m/W
R3 (Insulation Cond.)	:	1,128719664	K.m/W
R4 (Air Convection)	:	9,28017E-02	K.m/W
Total Resistance	**:**	**1,410634884**	**K.m/W**
	:	**67,84888214**	**W/m**
Q_{LOSS}	**:**	**0,067848882**	**kW/m**
	:	**0,277434079**	**kW**
Temperature Decrease	**:**	**413,84**	**K**
	:	**140,69**	**^oC**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Storage Tank (P) (65A) - Consumer Line

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	19699	mm
	:	19,699	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,69	^{o}C
	:	413,8370318	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450446	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296979**	**K.m/W**
	:	**101,0105954**	**W/m**
Q_{LOSS}	**:**	**0,101010595**	**kW/m**
	:	**1,989807718**	**kW**
Temperature Decrease	**:**	**413,67**	**K**
	:	**140,52**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Consumer Line (65A) - Distribution Line (150A)

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	14359	mm
	:	14,359	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,52	^{o}C
	:	413,6723	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,11838186	K.m/W
R2 (Oil Conduction)	:	0,00045045	K.m/W
R3 (Insulation Cond.)	:	0,7623567	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,94729698**	**K.m/W**
	:	**100,836698**	**W/m**
Q_{LOSS}	**:**	**0,1008367**	**kW/m**
	:	**1,44791415**	**kW**
Temperature Decrease	**:**	**413,55**	**K**
	:	**140,40**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Distribution Line (150A) - Deaerated Pipe

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	150A	
Schedule	:	80	
Outside Diameter	:	165,2	mm
Inner Diameter	:	154,2	mm
Thickness	:	11	mm
Total Length	:	8031	mm
	:	8,031	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,40	^{o}C
	:	413,55243	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,05320274	K.m/W
R2 (Oil Conduction)	:	0,00032255	K.m/W
R3 (Insulation Cond.)	:	0,37424159	K.m/W
R4 (Air Convection)	:	3,43747E-02	K.m/W
Total Resistance	**:**	**0,4621416**	**K.m/W**
	:	**206,435494**	**W/m**
Q_{LOSS}	**:**	**0,20643549**	**kW/m**
	:	**1,65788345**	**kW**
Temperature Decrease	**:**	**413,42**	**K**
	:	**140,27**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Suction of Circulation Pump from Deaerated Tank

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	80A	
Schedule	:	80	
Outside Diameter	:	89,1	mm
Inner Diameter	:	81,5	mm
Thickness	:	7,6	mm
Total Length	:	19934	mm
	:	19,934	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,27	^{o}C
	:	413,4151771	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,100660896	K.m/W
R2 (Oil Conduction)	:	0,000417397	K.m/W
R3 (Insulation Cond.)	:	0,663163799	K.m/W
R4 (Air Convection)	:	5,83519E-02	K.m/W
Total Resistance	**:**	**0,822594042**	**K.m/W**
Q_{LOSS}	**:**	**115,8106821**	**W/m**
	:	**0,115810682**	**kW/m**
	:	**2,308570136**	**kW**
Temperature Decrease	**:**	**413,22**	**K**
	:	**140,07**	**^{o}C**

Heat Loss of Insulated Thermal Oil Pipe Distribution

Scenario = Goes to Economizer from Pump

Pipe Parameters

Type	:	JIS G3454 STPG 370S	
Thermal Conductivity	:	34,00	W/mK
Nominal Size	:	65A	
Schedule	:	80	
Outside Diameter	:	76,3	mm
Inner Diameter	:	69,3	mm
Thickness	:	7	mm
Total Length	:	13933	mm
	:	13,933	m

Insulation Parameters

Type	:	IZOCAM GLASSWOOL	
Thickness	:	20	mm
Thermal Conductivity	:	0,0486	W/mK

Temperature Parameters

Fluid Temperature	:	140,07	^{o}C
	:	413,2240553	K
Ambient Temperature	:	45	^{o}C
	:	318,15	K
Air Convection Coeff.	:	50	W/m^2K
Oil Convection Coeff.	:	38,8	W/m^2K

Heat Loss Analysis

R1 (Oil Convection)	:	0,118381862	K.m/W
R2 (Oil Conduction)	:	0,000450462	K.m/W
R3 (Insulation Cond.)	:	0,762356698	K.m/W
R4 (Air Convection)	:	6,61080E-02	K.m/W
Total Resistance	**:**	**0,947296995**	**K.m/W**
	:	**100,3635141**	**W/m**
$\mathbf{Q_{LOSS}}$	**:**	**0,100363514**	**kW/m**
	:	**1,398364842**	**kW**
Temperature Decrease	**:**	**413,11**	**K**
	:	**139,96**	**^{o}C**

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ATTACHMENT M
HEATING DURATION CALCULATION

HFO STORAGE TANK PORTSIDE

HFO Storage Tank PS			
V	:	299,78	m^3
ρ_{HFO}	:	981,5	kg/m^3
m_{HFO}	:	294234,07	kg
	:	294,23407	ton
As	:	11,99	m^2
Heating Ratio	:	0,04	m^2/m^3
Ti	:	30,00	^oC
Td	:	45,00	^oC
Cp	:	1,90	kJ/kgK
Heating Coil Arrangement			
Material	:	SUS 316	
Standard	:	JIS G3459	
Schedule	:	40	
ND	:	50	
Out. Diameter	:	60,5	mm
	:	0,0605	m
Thickness	:	3,9	mm
	:	0,0039	m
Length	:	63,12	m
V_{TO} Inside	:	0,158733835	m^3
	:	158,7338352	L
ρ_{TO}	:	899,5	kg/m^3
m_{TO} Inside	:	142,7810847	kg
	:	0,142781085	ton

$$\rho_{15} = \rho_T + \alpha\,(T - 15^\circ C)$$

T test temperature

$\alpha = f(\rho)$ coefficient of thermal expansion for mineral oils, see the table

ρ [g/cm³]	α [g/(cm³·K)]
0,820 - 0,825	0,00068
0,825 – 0,840	0,00067
0,840 – 0,860	0,00066
0,860 – 0,870	0,00065
0,870 – 0,930	0,00064
0,930 – 1,000	0,00063

Capacity			
Boiler Pump	:		m^3/h
	:		m^3/s
Economizer Pump	:	23,7	m^3/h
	:	0,0066	m^3/s
Q_{HFO}	:	8385670,995	kJ
Q_{TO} Economizer	:	494,969	kW
Q_{TO} Boiler	:	3460,61	kW

Time Needed to Heat HFO using Economizer Pump				Time Needed to Heat HFO using Boiler Pump			
Q_{TO}	:	Q_{HFO}		Q_{TO}	:	Q_{HFO}	
495,0	:	(m x c x ΔT) / t		3460,6	:	(m x c x ΔT) / t	
t	:		s	t	:		s
	:	**4,706**	h		:	**0,673**	hours

HFO STORAGE TANK STARBOARD

HFO Storage Tank SB			
V	:	312,26	m^3
ρ_{HFO}	:	981,5	kg/m^3
m_{HFO}	:	306483,19	kg
	:	306,48	ton
As	:	12,49	m^2
Heating Ratio	:	0,04	m^2/m^3
Ti	:	30,00	^oC
Td	:	45,00	^oC
Cp	:	1,90	kJ/kgK
Heating Coil Arrangement			
Material	:	SUS 316	
Standard	:	JIS G3459	
Schedule	:	40	
ND	:	50	
Out. Diameter	:	60,5	mm
	:	0,0605	m
Thickness	:	3,9	mm
	:	0,0039	m
Length	:	63,75	m
V_{TO} Inside	:	0,160318156	m^3
	:	160,3181558	L
ρ_{TO}	:	899,5	kg/m^3
m_{TO} Inside	:	144,2061811	kg
	:	0,144206181	ton

$$\rho_{15} = \rho_T + \alpha\,(T - 15°C)$$

T test temperature

$\alpha = f(\rho)$ coefficient of thermal expansion for mineral oils, see the table

ρ [g/cm³]	α [g/(cm³·K)]
0,820 - 0,825	0,00068
0,825 – 0,840	0,00067
0,840 – 0,860	0,00066
0,860 – 0,870	0,00065
0,870 – 0,930	0,00064
0,930 – 1,000	0,00063

Capacity			
Boiler Pump	:	163,5	m^3/h
	:	0,0454	m^3/s
Economizer Pump	:	23,7	m^3/h
	:	0,0066	m^3/s
Q_{HFO}	:	8734770,915	kJ
Q_{TO} Economizer	:	494,467	kW
Q_{TO} Boiler	:	3460,61	kW

Time Needed to Heat HFO using Economizer Pump				Time Needed to Heat HFO using Boiler Pump			
Q_{TO}	:	Q_{HFO}		Q_{TO}	:	Q_{HFO}	
494,5	:	$(m \times c \times \Delta T) / t$		3460,6	:	$(m \times c \times \Delta T) / t$	
t	:	17665,030	s	t	:	2524,057	s
	:	**4,907**	h		:	**0,701**	hours

HFO SETTLING TANK

HFO Settling Tank			
V	:	23,74	m^3
ρ_{HFO} at 45°C	:	972,1	kg/m^3
m_{HFO}	:	23077,654	kg
	:	23,08	ton
As	:	4,75	m^2
Heating Ratio	:	0,20	m^2/m^3
Ti	:	45,00	°C
Td	:	60,00	°C
Cp	:	1,90	kJ/kgK
Heating Coil Arrangement			
Material	:	SUS 316	
Standard	:	JIS G3459	
Schedule	:	40	
ND	:	40	
Out. Diameter	:	48,6	mm
	:	0,0486	m
Thickness	:	3,7	mm
	:	0,0037	m
Length	:	31,11	m
V_{TO} Inside	:	0,049233686	m^3
	:	49,23368581	L
ρ_{TO}	:	899,5	kg/m^3
m_{TO} Inside	:	44,28570039	kg
	:	0,0442857	ton

$\rho_{15} = \rho_T + \alpha\,(T - 15°C)$

T test temperature

$\alpha = f(\rho)$ coefficient of thermal expansion for mineral oils, see the table

ρ [g/cm³]	α [g/(cm³·K)]
0,820 - 0,825	0,00068
0,825 – 0,840	0,00067
0,840 – 0,860	0,00066
0,860 – 0,870	0,00065
0,870 – 0,930	0,00064
0,930 – 1,000	0,00063

Capacity			
Boiler Pump	:	163,5	m^3/h
	:	0,0454	m^3/s
Economizer Pump	:	23,7	m^3/h
	:	0,0066	m^3/s
Q_{HFO}	:	657713,139	kJ
Q_{TO} Economizer	:	495,346	kW
Q_{TO} Boiler	:	3461,47	kW

Time Needed to Heat HFO using Economizer Pump				Time Needed to Heat HFO using Boiler Pump			
Q_{TO}	:	Q_{HFO}		Q_{TO}	:	Q_{HFO}	
495,3	:	(m x c x ΔT) / t		3461,5	:	(m x c x ΔT) / t	
t	:	1327,784	s	t	:	190,010	s
	:	**0,369**	h		:	**0,053**	hours

HFO SERVICE TANK PORTSIDE

HFO Service Tank PS / SB			
V	:	23,74	m^3
ρ_{HFO} at 90°C	:	962,65	kg/m^3
m_{HFO}	:	22853,311	kg
	:	22,85	ton
As	:	2,37	m^2
Heating Ratio	:	0,10	m^2/m^3
Ti	:	60,00	°C
Td	:	90,00	°C
Cp	:	1,90	kJ/kgK
Heating Coil Arrangement			
Material	:	SUS 316	
Standard	:	JIS G3459	
Schedule	:	40	
ND	:	50	
Out. Diameter	:	48,6	mm
	:	0,0486	m
Thickness	:	3,7	mm
	:	0,0037	m
Length	:	15,56	m
V_{TO} Inside	:	0,024624756	m^3
	:	24,62475575	L
ρ_{TO}	:	899,5	kg/m^3
m_{TO} Inside	:	22,14996779	kg
	:	0,022149968	ton

$$\rho_{15} = \rho_T + \alpha\,(T - 15°C)$$

T test temperature

$\alpha = f(\rho)$ coefficient of thermal expansion for mineral oils, see the table

ρ [g/cm^3]	α [$g/(cm^3\cdot K)$]
0,820 - 0,825	0,00068
0,825 – 0,840	0,00067
0,840 – 0,860	0,00066
0,860 – 0,870	0,00065
0,870 – 0,930	0,00064
0,930 – 1,000	0,00063

Capacity			
Boiler Pump	:	163,5	m^3/h
	:	0,0454	m^3/s
Economizer Pump	:	23,7	m^3/h
	:	0,0066	m^3/s
Q_{HFO}	:	1302638,727	kJ
Q_{TO} Economizer	:	495,346	kW
Q_{TO} Boiler	:	3461,47	kW

Time Needed to Heat HFO using Economizer Pump				Time Needed to Heat HFO using Boiler Pump			
Q_{TO}	:	Q_{HFO}		Q_{TO}	:	Q_{HFO}	
495,3	:	(m x c x ΔT) / t		3461,5	:	(m x c x ΔT) / t	
t	:	2629,753	s	t	:	376,325	s
	:	**0,730**	h		:	**0,105**	hours

HFO SERVICE TANK STARBOARD

HFO Service Tank PS / SB			
V	:	23,74	m^3
ρ_{HFO} at 90°C	:	962,65	kg/m^3
m_{HFO}	:	22853,311	kg
	:	22,85	ton
As	:	2,37	m^2
Heating Ratio	:	0,10	m^2/m^3
Ti	:	60,00	°C
Td	:	90,00	°C
Cp	:	1,90	kJ/kgK
Heating Coil Arrangement			
Material	:	SUS 316	
Standard	:	JIS G3459	
Schedule	:	40	
ND	:	50	
Out. Diameter	:	48,6	mm
	:	0,0486	m
Thickness	:	3,7	mm
	:	0,0037	m
Length	:	15,56	m
V_{TO} Inside	:	0,024624756	m^3
	:	24,62475575	L
ρ_{TO}	:	899,5	kg/m^3
m_{TO} Inside	:	22,14996779	kg
	:	0,022149968	ton

$$\rho_{15} = \rho_T + \alpha\,(T - 15°C)$$

T test temperature

$\alpha = f(\rho)$ coefficient of thermal expansion for mineral oils, see the table

ρ [g/cm³]	α [g/(cm³·K)]
0,820 - 0,825	0,00068
0,825 – 0,840	0,00067
0,840 – 0,860	0,00066
0,860 – 0,870	0,00065
0,870 – 0,930	0,00064
0,930 – 1,000	0,00063

Capacity			
Boiler Pump	:	163,5	m^3/h
	:	0,0454	m^3/s
Economizer Pump	:	23,7	m^3/h
	:	0,0066	m^3/s
Q_{HFO}	:	1302638,727	kJ
Q_{TO} Economizer	:	494,341	kW
Q_{TO} Boiler	:	3459,74	kW

Time Needed to Heat HFO using Economizer Pump				Time Needed to Heat HFO using Boiler Pump			
Q_{TO}	:	Q_{HFO}		Q_{TO}	:	Q_{HFO}	
494,3	:	(m x c x ΔT) / t		3459,7	:	(m x c x ΔT) / t	
t	:	2635,101	s	t	:	376,513	s
	:	**0,732**	h		:	**0,105**	hours

ATTACHMENT N
PIPE STRESS ANALYSIS SUMMARY OF SIMULATION IN SUSTAINED LOAD

STORAGE TANK PORTSIDE

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:10
Job Name: STORAGE STARBOARD REV
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 9.3 @Node 80
Code Stress: 12530.5 Allowable Stress: 135190.7
Axial Stress: 1638.8 @Node 98
Bending Stress: 11105.3 @Node 80
Torsion Stress: 1089.7 @Node 90
Hoop Stress: 3312.9 @Node 70
Max Stress Intensity: 12778.5 @Node 80

STORAGE TANK STARBOARD

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:6
Job Name: STORAGE PORT REV
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 10.6 @Node 468
Code Stress: 14336.0 Allowable Stress: 135190.7
Axial Stress: 1614.4 @Node 148
Bending Stress: 12949.2 @Node 468
Torsion Stress: 1391.1 @Node 440
Hoop Stress: 3312.9 @Node 70
Max Stress Intensity: 14501.2 @Node 469

SETTLING TANK

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:2
Job Name: SETTLING REV.
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 2.9 @Node 92
Code Stress: 3953.1 Allowable Stress: 135190.7
Axial Stress: 1290.3 @Node 99
Bending Stress: 2588.9 @Node 92
Torsion Stress: 508.4 @Node 89
Hoop Stress: 2730.0 @Node 70
Max Stress Intensity: 4184.5 @Node 92

SERVICE TANK PORTSIDE

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 13, 2017 Time: 16:37
Job Name: SERVICE PORT
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 2.3 @Node 191
Code Stress: 3079.7 Allowable Stress: 135190.7
Axial Stress: 1288.6 @Node 99
Bending Stress: 1823.1 @Node 191
Torsion Stress: 609.5 @Node 199
Hoop Stress: 2730.0 @Node 70
Max Stress Intensity: 3696.4 @Node 201

SERVICE TANK STARBOARD

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 13, 2017 Time: 16:41
Job Name: SERVICE SB
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 2.3 @Node 192
Code Stress: 3079.8 Allowable Stress: 135190.7
Axial Stress: 1276.9 @Node 99
Bending Stress: 1823.2 @Node 192
Torsion Stress: 609.5 @Node 199
Hoop Stress: 2730.0 @Node 70
Max Stress Intensity: 3696.5 @Node 201

ATTACHMENT O
PIPE STRESS ANALYSIS SUMMARY OF SIMULATION IN EXPANSION LOAD

STORAGE TANK PORTSIDE

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:10
Job Name: STORAGE STARBOARD REV
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 5 (EXP) L5=L2-L4

LOAD CASE DEFINITION KEY

CASE 5 (EXP) L5=L2-L4
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 5 (EXP) L5=L2-L4

Highest Stresses: (KPa) LOADCASE 5 (EXP) L5=L2-L4
Ratio (%): 7.8 @Node 79
Code Stress: 25628.9 Allowable Stress: 329024.3
Axial Stress: 763.0 @Node 230
Bending Stress: 25230.4 @Node 79
Torsion Stress: 3377.5 @Node 90
Hoop Stress: 0.0 @Node 20
Max Stress Intensity: 25628.9 @Node 79

STORAGE TANK STARBOARD

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:6
Job Name: STORAGE PORT REV
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 5 (EXP) L5=L2-L4

LOAD CASE DEFINITION KEY

CASE 5 (EXP) L5=L2-L4
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 5 (EXP) L5=L2-L4

Highest Stresses: (KPa) LOADCASE 5 (EXP) L5=L2-L4
Ratio (%): 12.0 @Node 460
Code Stress: 40062.9 Allowable Stress: 335110.8
Axial Stress: 745.2 @Node 390
Bending Stress: 39556.8 @Node 459
Torsion Stress: 2848.3 @Node 460
Hoop Stress: 0.0 @Node 20
Max Stress Intensity: 40062.9 @Node 460

SETTLING TANK

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:2
Job Name: SETTLING REV.
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 5 (EXP) L5=L2-L4

LOAD CASE DEFINITION KEY

CASE 5 (EXP) L5=L2-L4
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 5 (EXP) L5=L2-L4

Highest Stresses: (KPa) LOADCASE 5 (EXP) L5=L2-L4
Ratio (%): 6.0 @Node 90
Code Stress: 20297.7 Allowable Stress: 338905.7
Axial Stress: 502.1 @Node 90
Bending Stress: 19569.4 @Node 90
Torsion Stress: 1555.0 @Node 89
Hoop Stress: 0.0 @Node 20
Max Stress Intensity: 20297.7 @Node 90

SERVICE TANK PORTSIDE

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 13, 2017 Time: 16:37
Job Name: SERVICE PORT
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 5 (EXP) L5=L2-L4

LOAD CASE DEFINITION KEY

CASE 5 (EXP) L5=L2-L4
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 5 (EXP) L5=L2-L4

Highest Stresses: (KPa) LOADCASE 5 (EXP) L5=L2-L4
Ratio (%): 5.8 @Node 150
Code Stress: 19711.8 Allowable Stress: 339846.3
Axial Stress: 487.9 @Node 150
Bending Stress: 19215.3 @Node 150
Torsion Stress: 1858.2 @Node 109
Hoop Stress: 0.0 @Node 20
Max Stress Intensity: 19711.8 @Node 150

SERVICE TANK STARBOARD

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 13, 2017 Time: 16:41
Job Name: SERVICE SB
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 5 (EXP) L5=L2-L4

LOAD CASE DEFINITION KEY

CASE 5 (EXP) L5=L2-L4
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK PASSED : LOADCASE 5 (EXP) L5=L2-L4

Highest Stresses: (KPa) LOADCASE 5 (EXP) L5=L2-L4
Ratio (%): 6.7 @Node 98
Code Stress: 22648.7 Allowable Stress: 339785.9
Axial Stress: 487.7 @Node 150
Bending Stress: 22252.7 @Node 98
Torsion Stress: 1758.2 @Node 109
Hoop Stress: 0.0 @Node 20
Max Stress Intensity: 22648.7 @Node 98

ATTACHMENT P
SENSITIVITY ANALYSIS SUMMARY OF SIMULATION

STORAGE TANK PORTSIDE

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:25
Job Name: STORAGE STARBOARD REV
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK FAILED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1			
Ratio (%):	112.0	@Node	390
Code Stress:	151396.5	Allowable Stress:	135190.7
Axial Stress:	2269.4	@Node	390
Bending Stress:	148984.3	@Node	390
Torsion Stress:	44385.6	@Node	370
Hoop Stress:	3312.9	@Node	70
Max Stress Intensity:	150590.4	@Node	389

STORAGE TANK STARBOARD

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:24
Job Name: STORAGE PORT REV
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK FAILED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 114.1 @Node 158
Code Stress: 154225.2 Allowable Stress: 135190.7
Axial Stress: 2290.2 @Node 158
Bending Stress: 151905.5 @Node 158
Torsion Stress: 45040.0 @Node 170
Hoop Stress: 3312.9 @Node 70
Max Stress Intensity: 154225.2 @Node 158

SETTLING TANK

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416)   Date: JUL 14, 2017   Time: 13:24
Job Name: SETTLING REV.
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3   = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK FAILED   : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa   ) LOADCASE 4 (SUS) W+P1
Ratio (%):   107.0   @Node   158
Code Stress: 144645.3   Allowable Stress: 135190.7
Axial Stress: 1660.5   @Node   99
Bending Stress: 143128.8   @Node   158
Torsion Stress: 8161.3   @Node   110
Hoop Stress: 2730.0   @Node   70
Max Stress Intensity: 145441.1   @Node   150

SERVICE TANK PORTSIDE

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:18
Job Name: SERVICE PORT
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK FAILED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1

Ratio (%):	**105.8**	**@Node**	**149**
Code Stress:	**143016.3**	**Allowable Stress:**	**135190.7**
Axial Stress:	**1546.0**	**@Node**	**149**
Bending Stress:	**141360.3**	**@Node**	**149**
Torsion Stress:	**35786.8**	**@Node**	**170**
Hoop Stress:	**2730.0**	**@Node**	**70**
Max Stress Intensity:	**143016.3**	**@Node**	**149**

SERVICE TANK STARBOARD

CAESAR II 2014 Ver.7.00.00.2800, (Build 140416) Date: JUL 14, 2017 Time: 13:23
Job Name: SERVICE SB
Licensed To: SPLM: Edit company name in <system>\company.txt
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
CASE 4 (SUS) W+P1

LOAD CASE DEFINITION KEY

CASE 4 (SUS) W+P1
Piping Code: B31.3 = B31.3 -2012, Jan 10, 2013

CODE STRESS CHECK FAILED : LOADCASE 4 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 4 (SUS) W+P1
Ratio (%): 129.0 @Node 168
Code Stress: 174385.7 Allowable Stress: 135190.7
Axial Stress: 1545.1 @Node 88
Bending Stress: 172511.7 @Node 168
Torsion Stress: 65678.0 @Node 170
Hoop Stress: 2730.0 @Node 70
Max Stress Intensity: 174385.7 @Node 168